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MONTHLY WEATHER REVIEW

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CLIMATIC CHARACTERISTICS OF THE BOULDER DAM REGION

By George V. Sager

[Weather Bureau Office, Reno, Nev., June 27, 1934]

Boulder Dam is located in Black Canyon in the Colorado River about 30 miles southeast of Las Vegas, Nev., on the boundary line between Arizona and Nevada, in latitude 36°1′ north, longitude 114°44′ west. The name is a misnomer, having been given to the original project proposed for a dam in Boulder Canyon and continued in use after the site in Black Canyon was definitely chosen.

Work on the project started on September 17, 1930, when the rail connection between Las Vegas and the site of the dam was begun as the first unit. The estimated time of construction is 7 years, half of which has already passed. Construction has advanced rapidly and is now more than a year ahead of estimates.

The dam is of the arch-gravity type, 650 feet thick at the base, 45 feet at the top. The crest is to be 950 feet long and 582 feet above the river bed (surface of low water level). The river bed is 647 feet and the crest of the dam 1,229 feet above sea level.

The dam will form a reservoir 115 miles long, and from a few hundred feet to 8 miles wide, with an area of 227 square miles. It would take 2 full years average flow of the Colorado to fill the reservoir. As part of the flow must be permitted to pass down stream, it may be several years after storage begins before the dam is filled to capacity.

Black Canyon, in which the dam is located, is deep and narrow, with precipitous sides, as shown by the dam being only 950 feet long at a height of 582 feet. On the Arizona side the topography is rugged. On the Nevada side, after the rapid rise of the first few miles, the country is largely more rolling than mountainous, with some extensive level stretches.

The region in which the dam is situated is in the midst of the "Great American Desert." In Supön's classification it is in climatic province No. 26, North American Plateau and Mountain Province. "Great yearly and daily ranges. Dry." In Köppen's Botanical Classification it is in type B, the region of Xerophytes, plants which like dryness and high temperatures. In Ravenstein's Hygrothermal Types it is in type 8—"Warm and very dry."

In this study of the climate of the region consideration has been given to the records of those stations within 75 miles, air-line, from the dam. These include the site of the dam, Boulder City, Las Vegas, Logandale, Jean, and Searchlight in Nevada, and less than 50 miles distant from the dam, Fort Mohave and Needles, in Arizona and California, respectively, below the dam, and Kingman, Hackberry, and Truxton in the mountains of Arizona easterly from the dam and between 50 and 75 miles distant.

Boulder City, planned and constructed to house the workers on the project, is situated on rolling ground about 6 miles west-southwest of the dam at an elevation of 2,525 feet. The site was chosen to obtain the maximum of air drainage compatible with other essential factors and thus mitigate, so far as possible, the effects of the high summer temperatures of the region.

Las Vegas is situated in a broad valley at an elevation of 2,033 feet. Logandale is in the narrow valley of Muddy River at 1,400 feet elevation. Jean is in the northerly and easterly portion of a large valley which broadens out to the southward in California. The station is at an elevation of 2,864 feet and the valley floor ranges from 2,600 to 3,500 feet.

Searchlight is in the mountains near the southern tip of Nevada at an elevation of 3,445 feet. Kingman, Ariz., is on the highway from Los Angeles to Denver via Needles, Calif., and Flagstaff, Ariz., at an elevation of 3,326 feet; Hackberry, Ariz., is 20 miles northeast of Kingman, at 3,500 feet; Truxton is a few miles farther northeast, at 3,997 feet; Fort Mohave is on the Colorado River, elevation 540 feet; Needles, Calif., is a few miles south of Fort Mohave, and a few miles west of the Colorado River, at an elevation of 477 feet. Needles and Fort Mohave are in areas susceptible of irrigation by gravity from the dam.

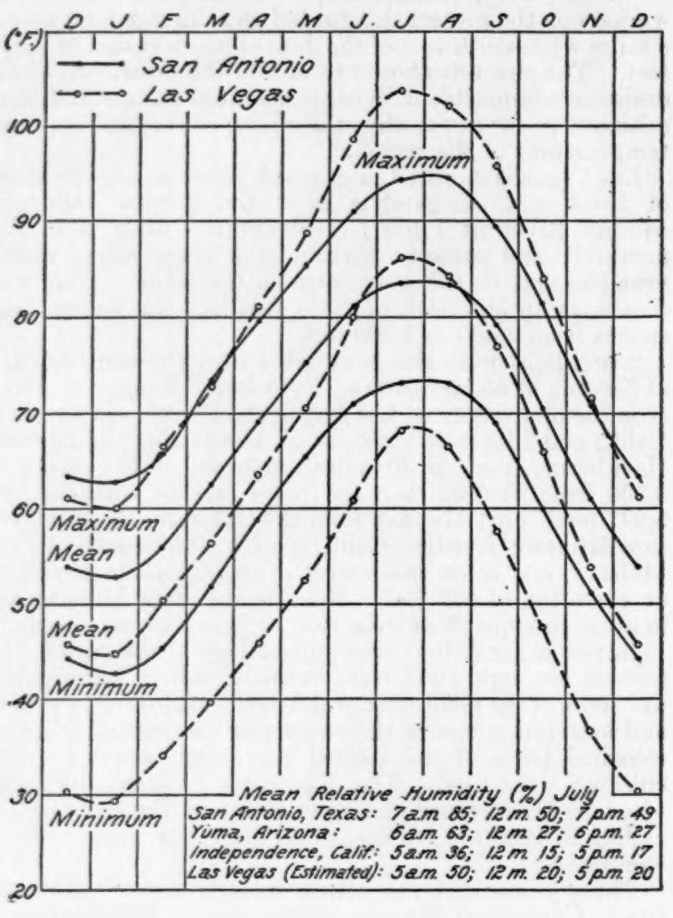
In preparing data on the climatology of the region, the records through 1933 were included where practicable. For some of the California and Arizona stations, the means and extremes given in the respective sections of "Climatological Data of the United States by Sections—1930 edition" were used. The differences between the mean of a long-term record ending in 1930 and the same record ending in 1933 are trifling, so all data may be considered comparable.

Three years of temperature records are available for Black Canyon at the site of the dam. This station is called Boulder Dam in the tables and text. The exact elevation is not available but it is approximately 650 feet above sea level. The record for these years was compared with the long-term records at Logandale and Needles. It was found that the long-term mean at Logandale was slightly lower month by month, and that at Needles, slightly higher during winter and lower during summer than the corresponding means, for the 3 years covered by the record, at Boulder Dam. When these results are applied to the record at Boulder Dam it appears that the temperatures for the 34- or 35-year period ending with 1933 were probably slightly lower in the months July to October and for March, and slightly higher in the other months of the year. The net annual change found was 0.1° cooler; the most important monthly

change was a reduction of the July mean temperature by 2.2° from 101.2° to 99°; thus showing that the 3 year's record 1931–33 represents nearly the true annual average temperature, and probably the extreme of high summer temperatures. These conclusions hold for the equally short record at Boulder City.

The short period of precipitation at Boulder City was in like manner compared with the long-term record at Las Vegas. The result showed a reduction in the annual quantity from 4.19 inches to 3.84 inches. The computed precipitation figures are used in the comparative tables.

Tables of mean monthly temperatures, mean maximum and mean minimum temperatures, mean daily ranges, highest and lowest temperatures of record, monthly and annual precipitation, greatest 24-hour rainfall, snowfall, wind, etc., for the stations in the vicinity of the dam



accompany this paper. Some comparative data for other well-known places have also been included.

The mean annual temperature at Boulder Dam is 72.8°; Fort Mohave, 72.1°; Needles, 71.8°. These are the lowest in elevation in the area and average approximately the same. Jean, Las Vegas, Logandale, and Boulder City, at elevations 1,400 to 2,900 feet, average 64° to 66°; Searchlight averages 64°; Kingman, 61° and Truxton, the highest station, 59°. The decrease of temperature with increase in elevation is thus clearly evident. The mean monthly temperature at Boulder Dam during July is 101.2°. That at Greenland Ranch in Death Valley, 178 feet below sea level and the hottest station in the United States, is 102°. The mean July maximum temperature at the dam is 113.2°, that at Greenland Ranch, 116.4°. The mean July minimum at Boulder Dam is 89.2°, at Greenland Ranch, 87.6°. The mean daily range during July is thus shown to be 24° at Boulder Dam and 29° at Greenland Ranch. The smaller daily range at Boulder Dam is probably due to it being "pocketed" in the Canyon, which cuts off the free nocturnal flow of air. Humidity in the Canyon may also be somewhat higher, lessening net loss of surface heat by radiation.

July mean temperatures at Needles average 94.1°; at Fort Mohave, 94.3°. Though lower in elevation and farther south their open exposure gives them 7° advantage over the site of Boulder Dam. Their average daily ranges are much wider: 28° at Needles; 35° at Fort Mohave; bringing average minimum temperatures down to 80° at Needles and 75° at Fort Mohave.

The mean July temperature at Boulder City, 90°, is 1° lower than that at Yuma, Ariz., and Imperial, Calif., and is 1° above that of Phoenix, Ariz. July means at Las Vegas, Logandale, Jean, and Searchlight average between 84° and 87° and compare with the University of Arizona, 86°, and San Antonio, Tex., 84°. They are only slightly above the average means at Galveston, 83°, and New Orleans, 82°.

Winter temperatures in the area are delightful, the January mean being 42° at Boulder City and 47° at Boulder Dam; the other Nevada stations and Kingman, Ariz., have means between these limits. Truxton has a January mean of 39°; Needles and Fort Mohave of 52°.

July maximum temperatures average 113° and minimum temperatures 89° at Boulder Dam. The July average maximum is 97° at Searchlight and 100° to 106° at the other Nevada stations. Truxton averages 95°, Kingman 97°. Mean minimum temperatures in July range from 64° at Truxton to 78° at Boulder City. The smallest daily range is 24° at Boulder City, the greatest, 37° at Logandale.

Closely related to mean maximum and mean minimum temperatures are the absolute extremes of temperature. The highest temperature officially recorded in the United States is 134° at Greenland Ranch in Death Valley. Boulder Dam runs this a close second with 128°. Needles has had 125°; Fort Mohave, 127°; Logandale, 119°; Las Vegas, 118°; Kingman, 117°; Jean, 116°; Boulder City, 112°; Searchlight and Truxton have had 110°. These, of course, were all in July or August. On the other hand, 22° has been recorded in winter at Boulder Dam, 31° at Needles, 18° at Fort Mohave, 12° at Boulder City and Searchlight, 8° at Las Vegas and Kingman, 6° at Logandale, −3° at Truxton, and −8° at Jean.

Being in the midst of the desert, precipitation is very scanty. The 3-year average at Boulder City has already been given as 4.19 inches, and the probable 35-year average as 3.84 inches. No record of precipitation is available at Boulder Dam, but, being 1,800 feet lower and evaporation from falling rain being great in such a region, it must necessarily be considerably less. Other annual averages are: Jean, 4.35 inches; Needles, 4.45 inches; Las Vegas, 4.79 inches; Logandale, 5.42 inches; Fort Mohave, 5.09 inches; Searchlight, 7.75 inches; Hackberry, 8.08 inches; Truxton, 9.91 inches and Kingman, 10.92 inches.

Comparing the average at Boulder City, 3.84 inches, with that of other dry stations we find that Clay City, Nev., has an average of 3.2 inches; Hot Springs, Churchill County, Nev., 3.37 inches; Thorne, Nev., 3.39 inches; Heber, Imperial Valley, Calif., 2.22 inches, and several other California stations less than 2.5 inches; while Greenland Ranch, Death Valley, the driest station in the United States, has a long-term average of only 1.45 inches. That portion of the area lower than 3,000 feet receives

only slightly more moisture than the driest portions of Imperial and Death Valleys, both below the level of the sea.

Characteristic of a desert, precipitation, when it does fall, comes largely in the form of heavy showers of short duration. The greatest 24-hour rainfall is 2 inches at Jean, 1.98 inches at Las Vegas, 2.38 inches at Logandale, 2.23 inches at Searchlight, and, probably owing to its short period of record, only 0.93 inch at Boulder City.

The tendency to infrequent, but heavy showers is further shown by the record of the average number of days with precipitation, 0.01 inch or more of rain or melted snow. The average number per year ranges from 15 at Fort Mohave to 25 at Logandale for the lower stations, and from 30 at Searchlight to 36 at Truxton for those above 3,000 feet.

Snow seldom falls; several winters pass at times at most stations without snowfall. Then there may be one storm with from a trace to several inches. The average annual quantities are made up of the depths from a few storms. The average annual depths are: Fort Mohave, "Trace"; Logandale, 0.4 inch; Las Vegas, 1.4 inch; Jean, 1.5 inch; Searchlight, 3 inches; Kingman, 4 inches; Truxton 6 inches.

The prevailing direction of the wind is from the south during 8 months, March to October, and from the north November to February, with south running a close second. At Las Vegas south predominates, even during the winter months. There is no record of wind movement, but, following the regime of desert regions, it is probably fairly large.

The record at Las Vegas shows that an average of 18 days monthly during winter, 19 monthly in spring, 20 monthly in summer and 22 monthly in fall are recorded as clear, and only 5 days monthly in winter, spring and summer, and 3 monthly in autumn, as cloudy. That at Logandale shows 19 clear days monthly in winter, 21 in spring, 23 in summer and 24 in autumn; 5 cloudy days monthly in winter, 3 in spring, 2 in summer, and 2 in fall. These are the only records readily available but they are fully representative of the region. Moreover, cloudy days in such a region are seldom, if ever, completely overcast.

The only record of relative humidity in the district is one of 18 to 19 days, at 7 a.m., 1 p.m., and 4 p.m., made at irregular intervals between July 12 and August 6, 1931, inclusive, at Boulder City, by the engineering force of Six Companies, Inc. These readings were made outside of the company's several dormitories, so are not strictly comparable. The temperature mean of the 7 a.m. observations is 82° and the relative humidity 27 percent. The temperature mean at 1 p.m. is 96° and the relative humidity 19 percent. At 4 p.m. the temperature mean is 97° and the relative humidity 17 percent. These relative humidities are characteristically low desert-type readings and compare well with humidities at the same temperature elsewhere in the desert. At Reno, for example, temperatures of 96° occurred at the time of 3 observations in July 1931 with average relative humidities of 15 percent. Yuma, with about the same average temperatures as Boulder City, has an average of 18 percent at noon and 6 p.m. during May and June but these rise to 27 percent during July and to 30 percent at noon and 32 percent at 6 p.m. during August. The comparison here is considerably in favor of Boulder City if we assume the few readings available to be representative, as they probably are. The relative humidity at New Orleans, in contrast, averages 63 percent at noon during the 3 summer months.

No record of evaporation is available. Lee's Ferry, Ariz., at 3,142 feet elevation and with 17,000 miles of wind annually averages 87 inches per year; Yuma, elevation 127 feet, wind movement 11,000 miles, averages 79 inches; Yuma Citrus Station, elevation 187 feet, wind movement 22,000 miles, averages 124 inches; Clay City, Nev., elevation 2,100 feet, and comparable as to exposure but with 64,000 miles wind, averages 142 inches. A study of these figures has led to the conclusion that the annual average evaporation at the lower stations in the Boulder Dam area could easily be above 100 inches from a land-surface exposure, but would probably be less than 50 inches from the reservoir owing in part to its protection from wind and partly to its lowish temperature, being fed largely from melted snows in the mountains of Colorado and Wyoming. The Bureau of Reclamation Engineers estimated annual losses by evaporation at 600,000 acre-feet, which would represent 41 inches of evaporation were the reservoir to be full all the time. As this would rarely be the case, their estimates must have been between 41 and 50 inches.

The capacity of the power plant below will be 1,000,000 to 1,200,000 horsepower to be sold at $0.00163 per kilowatt-hour for primary power, $0.0005 per kilowatt-hour for secondary. Eighteen percent of this is available to Nevada and the same quantity to Arizona. The question is frequently asked: Other conditions being favorable, would the climate of the region permit of the development of large industries and a large growth in population in the region of Boulder Dam, where this cheap power could be most economically used? The answer is emphatically, "yes." High daytime temperatures can be borne without injury and without serious discomfort in well-ventilated surroundings, and the wide daily range of temperature assures the opportunity to obtain a good night's rest. During 5 years in San Juan, P.R., I found that whenever the minimum temperature dropped below 78° I could count on a good night's rest. The relative humidity there averages 75 to 80 percent and the nights are very still. Furthermore, my sleeping apartment was not ideally arranged for ventilation. Had it been, nights with minimum temperatures 80° or 81° would not have caused difficulty. Galveston has a mean minimum in July of 78.6° and a moist climate. New Orleans has a July mean minimum of 75.4° and also a high humidity. The comparison is all to the advantage of Boulder City, whose mean minimum is 78.4° and whose humidity is low. Las Vegas and Logandale, in the area topographically best suited for industrial plants have mean July minima of 68° and 69°, respectively; Jean, 73°; Searchlight, 71°; Kingman, 66°; Truxton, 64°.

To give a graphic idea of the temperature conditions in this region as compared with some other location that is well known and has had a favorable development, a graph has been prepared (fig. 1) showing the relations between the maximum, minimum, and mean monthly temperatures at Las Vegas and at San Antonio, Tex. The latter is a city of considerable size, having with its suburbs a population of 280,000 at the last United States census and large manufacturing and commercial interests. While it would not be chosen for a summer resort, there is no question of the healthfulness of its climate and the well-being of its inhabitants.

Glancing first at the graphs of the mean temperatures we note that Las Vegas has the lower mean temperatures for more than 10 months of the year. From about June 21 to August 15 the mean temperature at Las Vegas is higher than that at San Antonio. Now looking at the graphs of the maximum and minimum temperatures we

note that the maximum temperature at Las Vegas is higher than that at San Antonio from about April 10 to November 15, lower than at San Antonio from November 15 to February 1 and about the same between February 1 and April 10. The minimum temperature at Las Vegas is 5° to 15° lower throughout the year. It is at once apparent that the midsummer period, June 20 to August 15, is the only part of the year when the comparison is to the disadvantage of Las Vegas. But a glance at the tables of relative humidities inserted beneath the graphs shows that this disadvantage is largely or entirely overcome by the more favorable humidity. A relative humidity of 20 percent at Las Vegas, as contrasted with 50 percent at San Antonio (noon readings), will undoubtedly more than offset the few degrees higher temperature at Las Vegas.

Thus, not only do the moderate night temperatures and low humidities make living conditions easily bearable in the probable industrial zone during the hottest months, but the records at the mountain stations indicate that there are many places within 2 hours by auto that would make ideal summer resorts or locations for summer homes. Furthermore, a glance at the fall, winter and spring temperatures and a consideration of the freedom of this region from storms and its high proportion of fair days and bright sunshine, leaves no doubt that the shores of the lake, which will be formed by the impounding of the waters of the Colorado, will have every climatic qualification for becoming recognized as a nearly ideal fall, winter and spring pleasure resort.

TEMPERATURES (°F.), BOULDER DAM REGION

TABLE 1.—*Mean monthly temperatures*

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Boulder City, Nev	42.0	44.8	58.0	62.9	70.0	83.2	90.4	88.7	82.0	69.3	55.6	43.9	65.9
Boulder Dam, Nev	47.3	53.1	65.0	72.6	79.7	89.9	101.2	97.0	88.7	75.4	57.3	46.5	72.8
Fort Mohave, Ariz	51.7	56.5	63.2	70.6	79.0	88.4	94.3	92.5	84.5	72.3	60.2	51.8	72.1
Jean, Nev	44.2	48.8	57.9	62.8	69.7	79.6	86.8	85.5	76.0	61.4	52.0	42.7	64.0
Las Vegas, Nev	44.6	50.3	56.2	63.3	70.4	79.9	86.1	84.3	76.7	65.7	53.7	45.5	64.7
Logandale, Nev	44.7	50.7	57.0	63.8	71.5	80.3	87.4	85.0	77.1	65.9	53.6	44.7	65.1
Needles, Calif	51.6	57.3	63.5	70.7	78.7	87.5	94.1	91.9	83.4	71.1	59.3	52.9	71.8
Searchlight, Nev	44.2	48.9	54.3	60.6	68.3	78.7	83.9	81.7	75.8	65.1	54.6	45.4	63.5
Kingman, Ariz	43.8	47.6	51.7	58.4	65.6	75.6	82.0	80.3	73.4	62.5	52.3	43.7	61.4
Truxton, Ariz	39.4	44.6	49.6	55.6	63.0	73.1	79.5	77.5	70.9	60.7	50.4	40.4	58.7

TABLE 2.—*Mean maximum temperatures*

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Boulder City, Nev	49.0	52.8	67.4	73.2	80.6	95.0	102.3	100.4	93.5	79.1	64.1	51.0	75.7
Boulder Dam, Nev	55.7	61.9	76.9	85.2	91.7	102.2	113.2	109.3	102.6	87.2	67.8	54.1	84.0
Fort Mohave, Ariz	64.7	71.2	77.1	86.8	93.4	104.7	109.8	107.6	100.6	86.6	75.1	63.5	86.8
Jean, Nev	57.4	61.0	69.6	77.3	84.2	95.4	100.4	100.0	90.2	74.8	64.4	55.1	77.5
Las Vegas, Nev	59.9	66.4	72.8	81.0	88.6	98.9	103.8	102.1	95.9	83.9	71.1	61.0	82.1
Logandale, Nev	59.0	65.4	73.2	81.6	90.3	100.5	105.8	103.1	96.1	84.3	70.3	59.1	82.4
Needles, Calif	63.5	69.8	77.3	85.6	93.6	103.6	107.9	105.2	98.6	85.1	72.0	62.6	85.4
Searchlight, Nev	53.1	58.7	65.6	72.9	81.3	92.3	97.1	94.6	88.4	76.5	65.2	54.8	75.0
Kingman, Ariz	56.7	61.4	66.4	74.6	82.3	93.8	97.4	95.5	89.8	78.6	67.0	56.4	76.7
Truxton, Ariz	52.5	59.3	66.0	72.0	80.0	91.7	94.9	93.1	87.2	77.7	66.7	54.8	74.7

TABLE 3.—*Mean minimum temperatures*

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Boulder City	35.0	36.8	48.4	52.6	59.5	71.4	78.4	77.0	70.4	59.5	47.2	36.8	56.1
Boulder Dam	38.9	44.2	53.0	60.0	67.7	77.6	89.2	84.8	74.7	63.6	46.8	38.9	61.6
Fort Mohave	38.7	41.8	47.2	54.2	61.3	69.3	75.2	74.7	65.6	54.6	44.2	35.3	55.2
Jean	31.2	36.6	46.1	48.2	55.2	63.8	73.2	71.0	61.6	48.0	39.6	30.3	50.4
Las Vegas	29.2	34.1	39.5	45.7	52.3	60.8	68.4	66.6	57.5	47.5	36.4	30.1	47.3
Logandale	30.5	36.0	40.6	46.6	52.7	59.9	69.0	66.6	58.1	47.5	37.0	30.4	47.9
Needles	38.8	44.3	49.3	55.1	63.2	70.9	80.1	77.5	67.0	55.7	45.5	39.8	57.3
Searchlight	35.3	39.2	43.0	48.3	55.4	65.1	70.8	68.5	63.3	53.7	44.0	35.9	51.6
Kingman	30.9	34.0	37.0	42.4	48.8	57.1	66.5	65.0	57.1	46.6	37.6	31.4	46.2
Truxton	26.3	29.8	34.4	39.1	46.0	54.6	64.0	62.2	55.0	44.0	34.3	26.8	43.0

TABLE 4.—*Mean daily ranges*

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Boulder City	14.0	16.0	19.0	20.6	21.1	23.6	23.9	23.4	23.1	19.6	16.9	14.2	19.6
Boulder Dam	16.8	17.7	23.9	25.2	24.0	24.6	24.0	24.5	27.9	23.6	21.0	15.2	22.4
Fort Mohave	26.0	29.4	29.9	32.6	32.1	35.4	34.6	32.9	35.0	32.0	30.9	28.2	31.6
Jean	26.2	24.4	23.5	29.1	29.0	31.6	27.2	29.0	28.6	26.8	24.8	24.8	27.1
Las Vegas	30.7	32.3	33.3	35.3	36.3	38.1	34.4	35.5	37.4	36.4	34.7	30.9	34.8
Logandale	28.5	29.4	32.6	35.6	37.6	40.6	36.8	36.1	38.0	36.8	33.3	28.7	34.5
Needles	24.7	25.5	28.0	30.5	30.4	32.7	27.8	27.7	31.6	29.4	26.5	22.8	28.1
Searchlight	17.8	19.5	22.6	24.6	25.9	27.2	26.3	25.9	25.1	22.8	21.2	18.9	23.1
Kingman	25.8	27.4	29.4	32.4	33.5	36.7	30.9	30.5	32.7	32.0	29.4	25.0	30.5
Truxton	26.2	29.5	31.6	32.9	34.0	37.1	30.9	30.9	32.2	33.7	32.4	28.0	31.7

TABLE 5.—*Extreme maximum temperatures*

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Boulder City	69	75	88	93	98	107	112	112	105	91	78	67	112
Boulder Dam	74	86	96	105	107	115	128	124	115	99	81	70	128
Fort Mohave	81	92	103	110	117	127	124	124	117	108	94	81	127
Jean	78	79	88	95	112	116	116	110	106	91	83	78	116
Las Vegas	80	89	96	102	114	113	118	115	110	101	89	91	118
Logandale	87	86	93	103	114	117	119	117	114	101	91	79	119
Needles	83	90	96	106	118	122	125	122	116	112	90	86	125
Searchlight	76	76	82	94	101	110	109	107	102	95	86	78	110
Kingman	78	81	95	102	106	110	112	117	107	99	89	77	117
Truxton	77	78	84	89	106	110	110	106	99	95	89	74	110

TABLE 6.—*Extreme minimum temperatures*

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Boulder City	28	12	35	31	38	52	66	67	58	46	26	17	12
Boulder Dam	30	22	39	46	50	60	67	73	61	49	33	29	22
Fort Mohave	18	24	31	30	37	52	58	54	48	35	24	18	18
Jean	−6	18	24	24	30	43	46	40	31	28	14	4	−6
Las Vegas	8	10	16	26	28	35	40	47	38	29	14	12	8
Logandale	6	17	19	25	29	40	49	48	37	29	19	10	6
Needles	21	23	28	33	39	46	60	60	40	36	25	23	21
Searchlight	14	17	22	30	30	40	58	51	43	34	15	12	12
Kingman	8	11	16	20	29	34	45	43	31	27	13	9	8
Truxton	−3	3	16	23	29	38	41	40	38	25	10	0	−3

TABLE 7.—*Comparative temperatures*

Stations	Number of years record	Mean temperatures		Mean maximum temperatures		Mean minimum temperatures		Mean daily range	
		Jan.	July	Jan.	July	Jan.	July	Jan.	July
Boulder City	2-3	42.0	90.4	49.0	102.3	35.0	78.4	14.0	23.9
Boulder Dam	3	47.3	101.2	55.7	113.2	38.9	89.2	16.8	24.0
Las Vegas	23-25	44.6	86.1	59.9	103.8	29.2	68.4	30.7	35.4
Logandale	28	44.7	87.4	59.0	105.8	30.5	69.0	28.5	36.8
Jean	6-9	44.2	86.8	57.4	100.4	31.2	73.2	26.2	27.2
Searchlight	20	44.2	83.9	53.1	97.1	35.3	70.8	17.8	26.3
Needles	31	51.6	94.1	63.5	107.9	38.8	80.1	24.7	27.8
Imperial, Calif	5	54.2	91.2	70.6	106.0	37.0	75.3	33.6	30.7
Yuma, Ariz	53	54.5	91.0	66.8	105.4	42.2	76.6	24.6	28.8
Phoenix, Ariz	27	51.8	89.2	64.2	102.4	39.5	76.0	24.7	26.4
University of Arizona, (Tuscon)	35	50.0	85.6	65.1	98.7	34.9	72.4	30.2	26.3
San Antonio, Tex	36	52.7	83.5	62.6	94.0	42.5	72.9	20.1	21.1
Galveston, Tex	49	55.9	83.4	57.0	88.0	45.8	78.6	11.2	9.4
New Orleans, La	60	54.7	82.4	62.3	89.3	47.0	75.4	15.3	13.9
Greenland Ranch, Calif	20	51.4	102.0	64.9	116.4	36.9	87.6	28.0	28.8
Fort Mohave	44	51.7	94.3	64.7	109.8	38.7	75.2	26.0	34.6
Kingman	27	43.8	82.0	56.7	97.4	30.9	66.5	25.8	30.9
Truxton	14	39.4	79.5	52.5	94.9	26.3	64.0	26.2	30.9

TABLE 8.—*Precipitation, Boulder Dam Region*

[Inches and hundredths]

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Boulder City [1]	0.50	0.50	0.25	0.21	0.17	0.14	0.45	0.49	0.33	0.24	0.19	0.37	3.84
Fort Mohave	.61	.94	.45	.25	.11	.05	.21	.71	.13	.28	.45	.90	5.09
Jean	.61	.33	.45	.26	.01	T	.40	.27	.76	.60	.40	.26	4.35
Las Vegas	.63	.62	.31	.26	.21	.17	.56	.61	.42	.30	.24	.46	4.79
Logandale	.92	.65	.55	.27	.16	.13	.45	.55	.30	.55	.35	.54	5.42
Needles	.60	.48	.43	.18	.11	.06	.37	.74	.33	.26	.35	.54	4.45
Searchlight	1.09	.87	.59	.61	.25	.16	.94	1.53	.43	.47	.21	.60	7.75
Nelson and El Dorado Canyon													7.24

[1] 2-3 years of record. Extended by comparison with Las Vegas.

TABLE 9.—*Comparative precipitation*

Clay City, Nev.; east edge of Death Valley region	3. 20
Hot Springs, Churchill County, Nev	3. 37
Greenland Ranch, Death Valley, Calif.; elevation 178 feet	1. 45
Heber, Imperial Valley, Calif.; elevation 20 feet below sea level	2. 22
Bagdad, San Bernardino County, Calif.; elevation 784 feet	2. 28

TABLE 10.—*Greatest precipitation in 24 hours*

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Boulder City	0. 44	0. 44	T	0. 39	0. 26	0. 04	0. 60	0. 68	0. 65	0. 13	0. 61	0. 93	0. 93
Jean	1. 25	. 75	1. 30	1. 00	. 10	T	1. 85	. 50	2. 00	1. 00	1. 25	. 40	2. 00
Las Vegas	1. 55	. 96	1. 55	. 63	1. 03	. 45	1. 98	1. 35	1. 00	1. 40	. 86	1. 35	1. 98
Logandale	1. 63	1. 45	1. 19	. 90	1. 20	1. 20	. 94	2. 38	1. 42	1. 04	2. 00	1. 62	2. 38
Searchlight	2. 23	1. 66	1. 57	1. 06	. 67	. 49	1. 60	3. 30	2. 02	1. 69	. 70	1. 81	2. 23

TABLE 11.—*Days with 0.01 inch or more of precipitation*

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Boulder City	2	3	0	2	2	1	4	1	2	1	2	3	23
Fort Mohave	2	3	2	1	0	0	1	2	1	1	1	1	15
Las Vegas	2	2	2	1	1	1	2	2	1	1	1	2	18
Logandale	3	3	3	2	1	1	3	2	1	2	1	3	25
Needles	2	2	2	1	1	0	2	2	1	1	1	2	17
Searchlight	3	3	3	2	2	1	4	4	2	2	1	3	30
Kingman	3	4	4	3	1	1	4	5	3	2	2	3	35
Truxton	3	3	3	2	2	1	6	6	3	2	2	3	36

TABLE 12.—*Snowfall; monthly and annual averages*

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Fort Mohave	T	0	0	0	0	0	0	0	0	0	0	T	T
Jean	0. 4	0. 2	0	T	T	0	0	0	0	0	0	0. 9	1. 5
Las Vegas	0. 6	T	T	T	0	0	0	0	0	0	T	0. 8	1. 4
Logandale	T	0. 1	0	0	0	0	0	0	0	0	0. 1	0. 2	0. 4
Searchlight	1. 2	0. 4	0. 4	T	T	0	0	0	0	0	0. 1	0. 9	3. 0
Kingman	1. 6	0. 4	0. 4	T	0	0	0	0	0	0	0. 5	1. 1	4. 0
Truxton	1. 9	1. 1	0. 8	0	0. 1	0	0	0	0	0	0. 1	1. 7	5. 7

TABLE 13.—*Wind; prevailing direction*

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Las Vegas	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
Logandale	n.	n.	s.	s.	s.	s.	s	s.	s.	s.	n.	n.	s.
Fort Mohave	n.	s.	s.	s.	s.	s.	s.	s.	s.	n	n.	n.	s.
Needles	n.	n.	s.	w.	w.	s.	s.	s.	s.	w.	n.	n.	s.

TABLE 14.—*Relative humidity (percent) [comparative]*

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Yuma, Ariz.:													
6 a.m.	57	59	58	56	57	56	63	68	66	61	57	57	60
12 m.	28	27	22	20	18	18	27	32	29	26	26	34	26
6 p.m.	33	30	25	19	18	18	27	30	28	29	33	37	27

Stations	Winter	Spring	Summer	Fall	Year
New Orleans, La.					
8 a.m.	85	83	83	83	84
12 m.	68	62	63	62	64
8 p.m.	73	69	72	72	72

	Number observations	Mean temperature	Mean relative humidity
Boulder City, Nev.; mean temperatures and relative humidities, 18 to 19 daily observations between July 12 and Aug. 6, 1931:			
7 a.m.	18	82. 4	27
1 p.m.	18	96. 5	19
4 p.m.	19	97. 1	17

TABLE 15.—*Average annual evaporation*

	Elevation feet	Average annual wind	Average annual total evaporation
			Inches
Lees Ferry	3, 142	17, 280	87
Yuma Citrus	187	21, 700	124
Yuma	127	11, 000	79
Clay City	2, 185	64, 000	142

NOTE.—Engineer's estimate for Boulder Lake 41 plus, inches.[1] 65 percent [2] of 79 inches, evaporation at Yuma, equals 51 inches.

[1] 600,000 acre-feet divided by 145,000 (maximum area of reservoir in acres).
[2] Generally accepted relation between land station and open water exposure.

TABLE 16.—*Days clear, partly cloudy and cloudy, Boulder Dam region*

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Las Vegas:													
Clear	18	16	19	18	20	22	19	21	22	23	21	20	239
Partly cloudy	8	7	6	6	5	4	7	5	5	5	6	6	70
Cloudy	5	5	5	6	6	4	5	5	3	3	3	5	56
Logandale:													
Clear	20	18	21	21	22	25	21	23	24	26	23	20	264
Partly cloudy	6	6	7	6	6	4	7	6	4	3	4	5	64
Cloudy	5	4	3	3	3	1	3	2	2	2	3	6	37

THE GREAT WIND OF APRIL 11-12, 1934, ON MOUNT WASHINGTON, N.H., AND ITS MEASUREMENT

PART I

WINDS OF SUPERHURRICANE FORCE, AND A HEATED ANEMOMETER FOR THEIR MEASUREMENT DURING ICE-FORMING CONDITIONS [1]

By SALVATORE PAGLUICA

[Mount Washington, N.H. (post office, Gorham, N.H.), July 1934]

Early methods and results.—While this article discusses chiefly the extremely high winds which have long been known to occur on Mount Washington, N.H., that portion of it which describes the sturdy heated anemometer recently built for this station, and which automatically frees itself from rime and ice during the most extreme winter conditions, is of more general interest since this device is suitable for all localities subject to such conditions.

The character of the winds prevailing on the stormy summit of Mount Washington was well determined by the observations beginning June 5, 1871, and maintained throughout the years for more than 17 years by the United States Signal Corps.

Extremely high average wind movements were recorded the year around, and velocities in excess of 100 miles per hour were frequently experienced, particularly during the winter months. A parallel with free-air conditions could not be satisfactorily established, and explanations of these unusually high surface-wind velocities were hypothetical and qualitative.

The chief difficulties experienced by the United States Signal Service in connection with wind measurement on Mount Washington were:

1. Ordinary cup anemometers could not stand the terrific impact of superhurricane winds.
2. The presence of rime-forming fog on the summit 9 months of the year, and during some of the winter months more than 50 percent of the time.

Rime depositing on the rotor would slow it down gradually to a standstill, and generally bend the cup arms.

The first problem was partly solved by building a rugged, heavily-braced cup anemometer of standard dimensions. Doubtless due to the complete absence in those early days of wind tunnels or other means of adequately testing such instruments, very little is said on the performance of this instrument in the station records or the reports of the Chief Signal Officer. In fact, its run was assumed to be the same as that of the lighter cup wheels, namely, 500 rotations to the indicated mile.

One of these instruments was subjected to a single test run in 1922 by Mr. S. P. Fergusson. This test, extended to a wind speed of 136 miles per hour, showed that from 20 miles per hour upward the light cup wheels ran from 8 to 10 percent faster than the heavy pattern. This means that all such high velocities recorded in the past at Mount Washington are more nearly true velocities than heretofore supposed.

The observatory journal, however, as late as 1886, reports that anemometer cups were still being blown off and records lost.

The solution of the problem of rime forming on the cups was attempted at the expense of considerable effort. The observers were instructed to change the anemometers frequently during periods of rime-formation—an operation often performed with great difficulty and hardship. In October 1887, the journal reads: "Anemometer being froze up was removed from the roof for the winter." In March 1881: "During March 1881, frost formation prevented wind velocity readings on 27 days."

The new method.—It was obvious at the time of reoccupancy of the summit of Mount Washington for meteorological observations, October 1932, that a new method should be tried in order to obtain a continuous record of wind movement. The conventional type of cup anemometer was replaced by an instrument having a specially designed cup-wheel rotor equipped with a stationary electric stove unit, connected with the 110-volt D.C. gasoline-electric unit of the Observatory. This new instrument, installed on the observatory building, 8 feet above the roof-ridge, recorded every mile of wind on a chronograph the charts of which were changed weekly. Heat was applied during the long and frequent periods of rime and ice-deposition. A maximum velocity of 164 mi./hr. was recorded April 5, 1933.

Early experience proved the inadequacy of this design and the need of improvements. A new anemometer, described in the next part, designed with the cooperation of those who were acquainted with the deficiencies of the first instrument, was built early in 1933 by the Mann Instrument Co., 23 Church Street, Cambridge, Mass., with the aid of the Permanent Science Fund of the American Academy of Arts and Sciences.

The velocity-characteristic of the new instrument is far from ideal, and its sensitiveness at velocities below 10 miles per hour is practically zero. Its chief purpose, however, is to record continuously, with the accuracy of modern methods of standardization, rimeforming winds of superhurricane force. Low wind velocities, which in the winter months give a negligible fraction of the total wind movement, are measured by a cup anemometer exposed on a structure 30 feet above the geographical summit.

The new heated anemometer (fig. 6), securely installed 10 feet above the roof ridge, has proved to be entirely satisfactory, the only trouble experienced during the whole winter having been a damaged ball bearing, and a burnout of the auxilliary (air-gap) heater. In both instances the spare no. 1 anemometer secured the record while the no. 2 instrument was being repaired.

A few breaks in the continuity of the records last winter (1933-34) were due to improper operation of the gasoline-electric unit at very low temperatures. In most cases, however, it was possible to interpolate average wind velocities with a fair degree of accuracy.

The calibration of the no. 2 anemometer and the extrapolation of corrections are fully discussed in part III, page 191.

The anemometer functioned perfectly in foggy weather, at a temperature of 46.5° F. below zero in a wind that averaged 100 mi./hr. and increased to 120 mi./hr. as the air temperature rose to 42° F. below.

THE STORM OF APRIL 11-12,1934

The low pressure which caused the greatest 24-hour wind movement ever recorded on Mount Washington,

[1] Paper read at the meeting of the American Meteorological Society, Washington, D.C., April 1934.

N.H., and the highest wind velocity ever officially recorded anywhere in the world by accurately-tested instruments, was preceded there by a period of 48 hours of fair weather with normal pressure, temperature, and other meteorological elements. On the afternoon of April 10 a singular period of near calm was experienced. But the pressure fell slowly from the afternoon of April 11 until 6 a.m., April 12, and then more rapidly (fig. 1), under the influence of the low-pressure area centering over the eastern part of the Great Lakes region.

On the morning of April 11, there was an emissary sky with Cirrostratus, Cirrus densus, Cirrus filosus, and some Altocumulus lenticularis, moving from the west. At 8 a.m. low Stratocumulus was seen rapidly advancing over an extended front from the east. At 11 a.m., while the upper sky was covered with eight-tenths Cirrostratus filosus, Cirrus filosus, and Cirrus densus, the low Stratocumulus from the east began arching over the summit of the mountain. The southeast wind had reached a velocity of 80 miles per hour, [2] and was steadily increasing. The temperature held about 22° F. without any appreciable change. Rough frost began forming soon after the summit became enveloped by clouds.

The afternoon of April 11 was characterized by a heavy southeast wind of moderate gustiness, reaching a maximum of 136 miles per hour. During the following night the hourly wind movement was never less than 107 miles (fig. 1) and rough frost formed rapidly.

The morning of April 12 was characterized by a rapidly increasing southeast wind of appreciable gustiness, steadily falling pressure, slightly rising temperature from a minimum of 15° F., reached at 2 a. m., and a light fall of granular snow. Rough frost accumulated heavily throughout the day, with a fairly well defined feathery appearance, icy structure, high water content, and producing a characteristic deep-blue light reflection.

At the time of, and just after, the great storm the records were read and corrections worked out somewhat hurriedly, but nevertheless as carefully as possible. Moreover, as the maximum test speed was about 143 mi./hr. the corrections of the superhurricane wind gusts of over 200 mi./hr. involved somewhat uncertain extrapolations of the calibration curve. However, the outstanding features of the record are presented briefly below.

In the course of preparation of this paper, and in order to establish all the facts of such important records, arrangements were made with the cooperation of the Chief of the Weather Bureau and the Director of the Bureau of Standards to subject the anemometer to one or more new tests. The attention of the reader is invited to Dr. C. F. Marvin's discussion of all the tests and his refined analysis of the record and extrapolation of corrections beginning page 191.

At noon, April 12, the hourly wind movement had risen to 155 miles with gusts reaching a velocity well above 200 mi./hr. From 12 noon to 1 p.m., while other conditions were comparatively unchanged, the wind attained its extreme force. Between 12:25 p.m. and 12:30 p.m., a 5 minute average wind velocity of 188 mi./hr. was recorded on the Weather Bureau type multiple register (fig. 2). Gusts were frequently timed by two observers, with stop-watch and Nardin chronometer, and the values obtained corrected by means of the extrapolated calibration curve of the United States Bureau of Standards, (fig. 9–A).

[2] Unless otherwise indicated all velocities are given in true miles per hour.

While frequent values of 225 mi./hr., including two-thirds mile at this speed, were obtained, several gusts of 229 mi./hr. were timed, and at 1:21 p.m. the extreme value of 231 mi./hr. for a succession of 3 one-tenth mile contacts was timed twice. This is the highest natural wind velocity ever officially recorded by means of an anemometer on Mount Washington or anywhere else.

The hourly movement between 12 noon and 1 p.m. reached a peak of 173 miles.

The barograph, 6,284 feet above sea level, showed vigorous oscillations of two-tenths inch maximum amplitude. The lowest pressure of 22.82 inches was recorded at 12:45 p.m.

In the afternoon the force of the wind decreased rapidly, while the snowfall increased in intensity. The pressure rose rapidly between 4 p.m. and 6 p.m. and more gradually thereafter. At 8 p.m. the total snowfall for the previous 24 hours was 10 inches and had a water equivalent of 3.78 inches. The huge accumulation of rough frost had reached a maximum thickness of 3 feet on the most exposed objects.

The maximum 24-hour wind movement was obtained between 4 p.m. April 11, and 4 p.m. April 12, with a total of 3,095 miles and an average of 129 mi./hr.

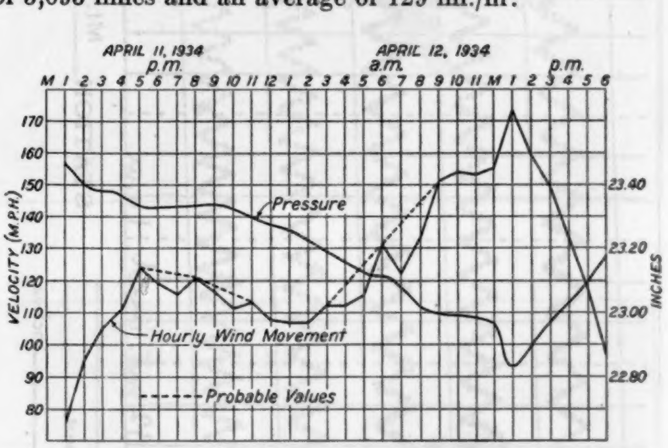


FIGURE 1.—Air pressure and average hourly wind travel Mount Washington, N.H., elevation, 6,284 feet, April 11 to 12, 1934.

Although the anemometer was well exposed to the southeast wind, the rapid accumulation of rough frost around the lower portion of the 10-foot staff seemed to have had the tendency to break somewhat the force of the wind, since the wind-movement curve (fig. 1) shows decided increases of velocity following each cleaning of the anemometer post immediately below the instrument. The figures obtained, therefore, should be considered as somewhat conservative.

Every mile of wind was recorded by the special electrically heated anemometer.

No serious difficulty was experienced by the observers in attending to their outdoor duties necessary under the extreme conditions. The much discussed question whether a man can stand up under the heavy pressure of such a strong wind remains still a matter of speculation. Experienced men seem to react to the impact of the wind with various adjustments such as bending themselves toward the wind, lowering the body by spreading the legs, and exposing the side of the body to the wind. These various counteractions, difficult to evaluate in terms of force, and variable with different individuals, together with the fact that the wind pressure is less by one-fifth part or more at the summit than at sea level make it possible for persons

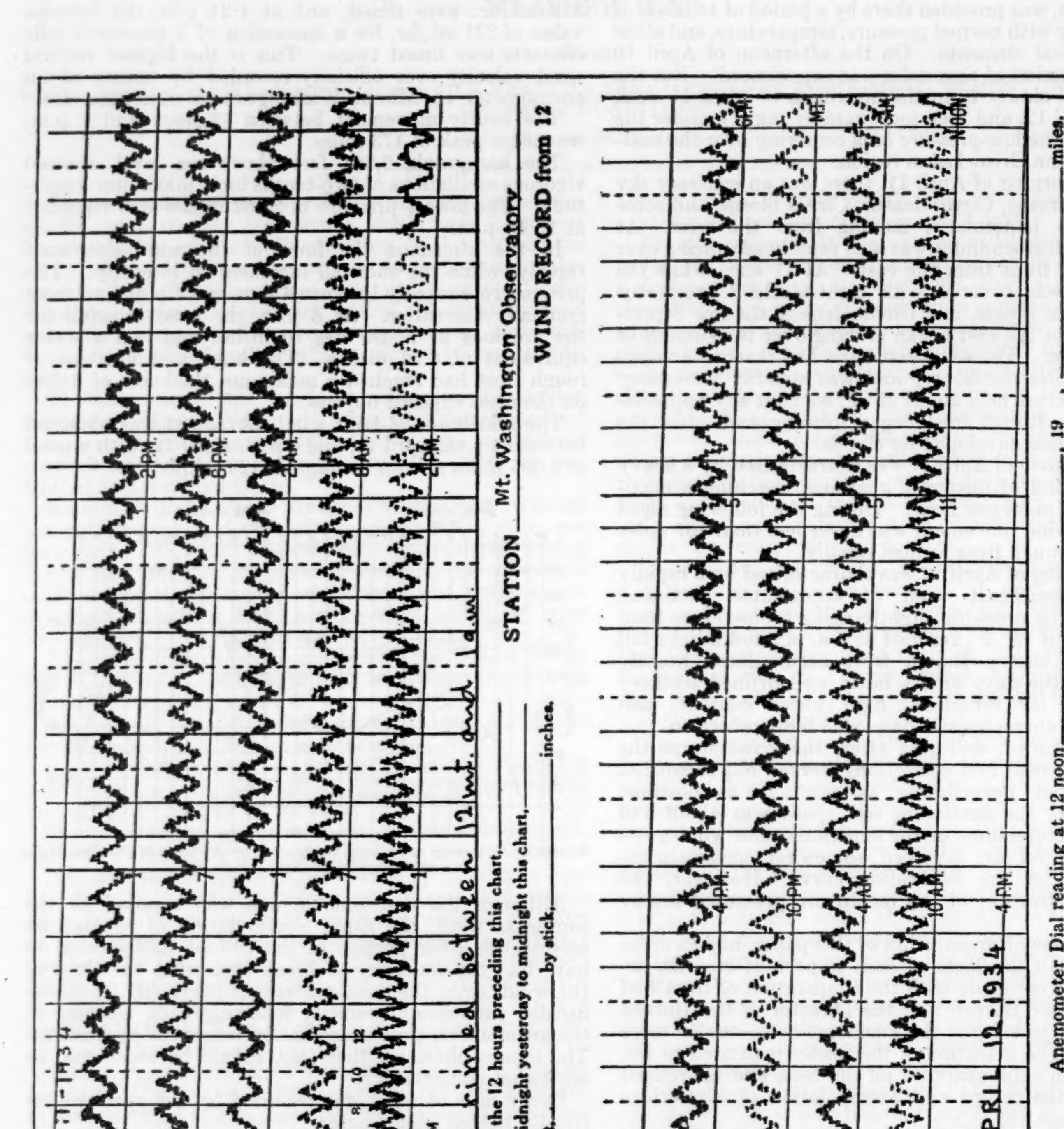


FIGURE 2.—Full-scale copy of record of wind velocity from 12:10 p.m. April 11, to 1:30 p.m. April 12. Wind direction generally from the southeast.

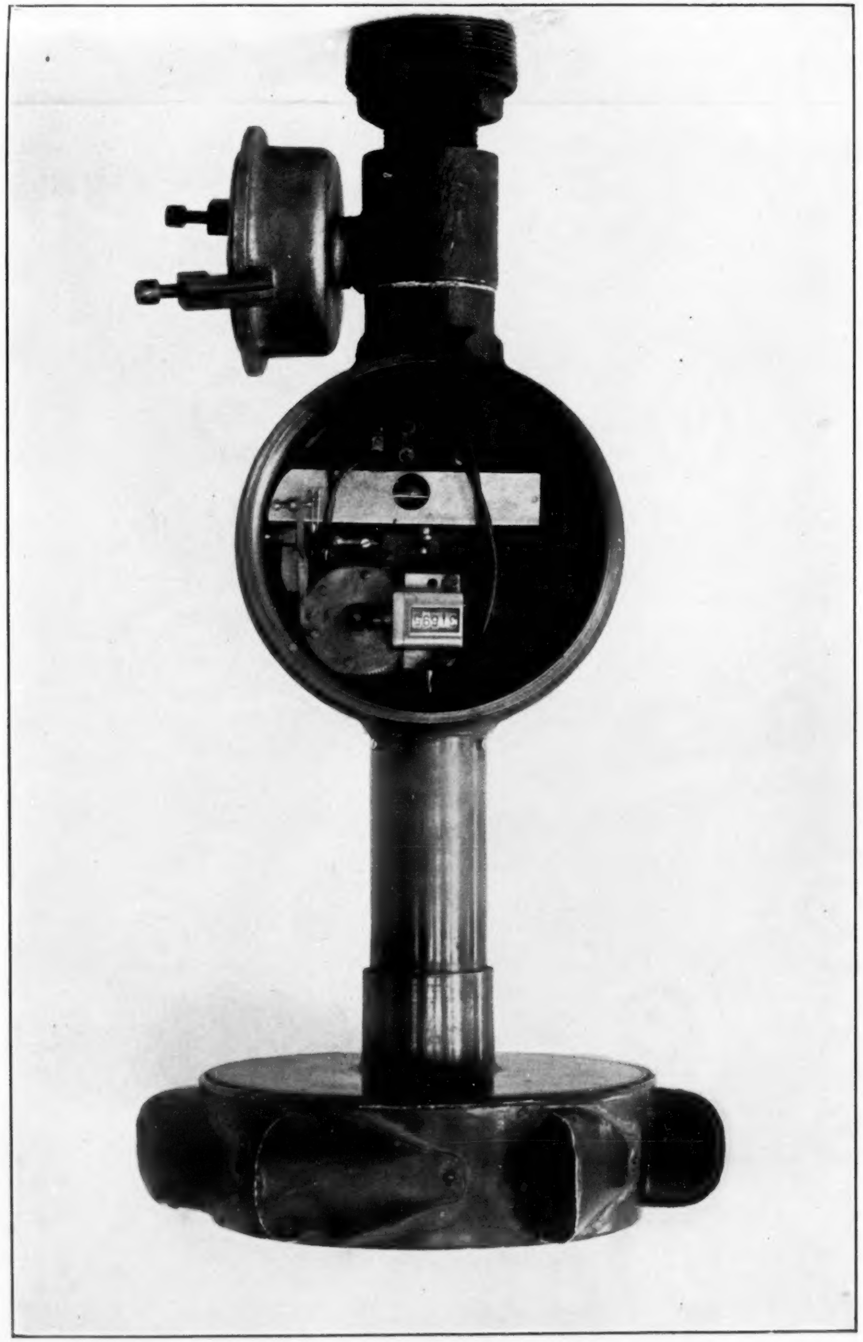


FIGURE 3.—Perfected heated anemometer no. 2, showing dial mechanisms.

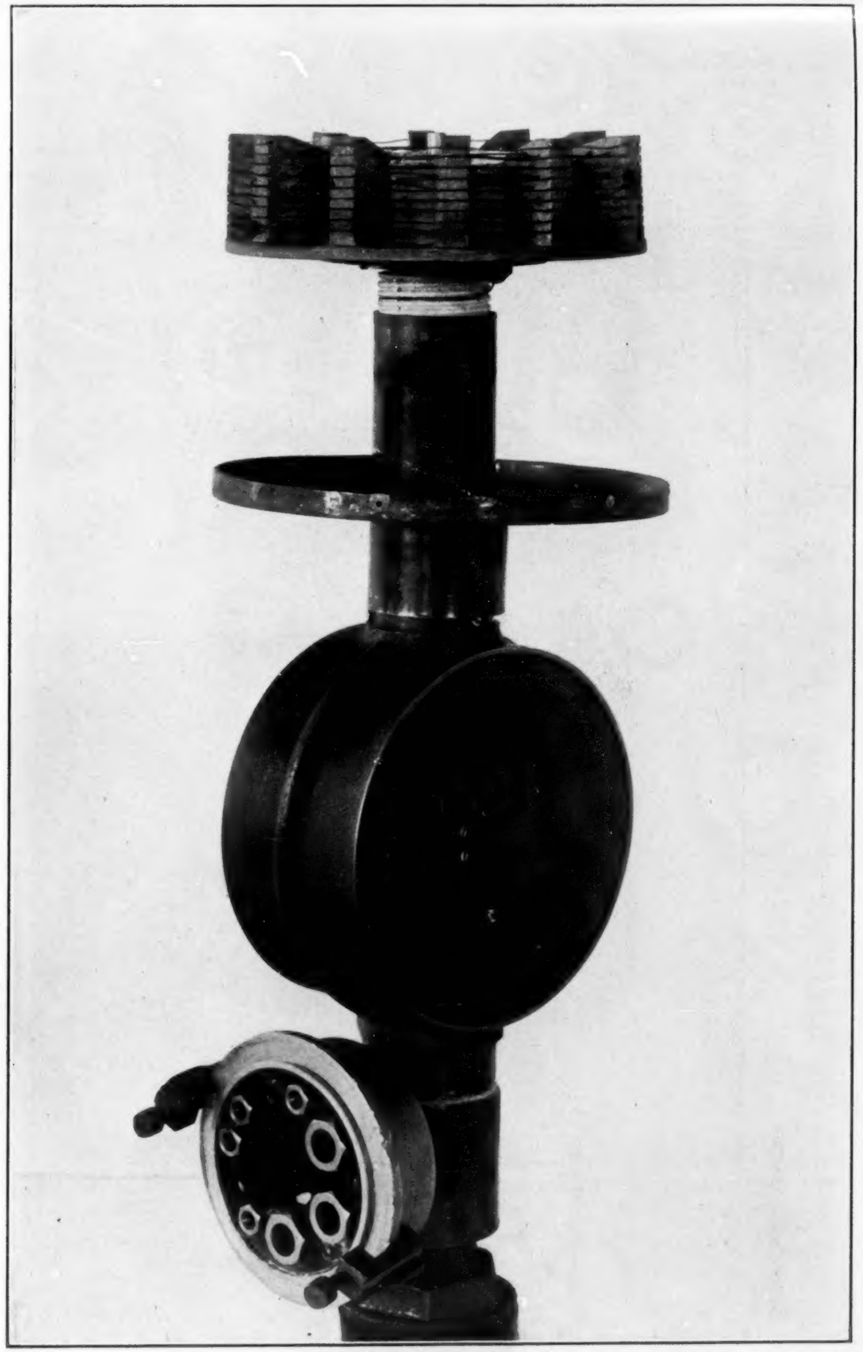


FIGURE 4.—Anemometer with rotor removed and undercover lowered to show heating coils.

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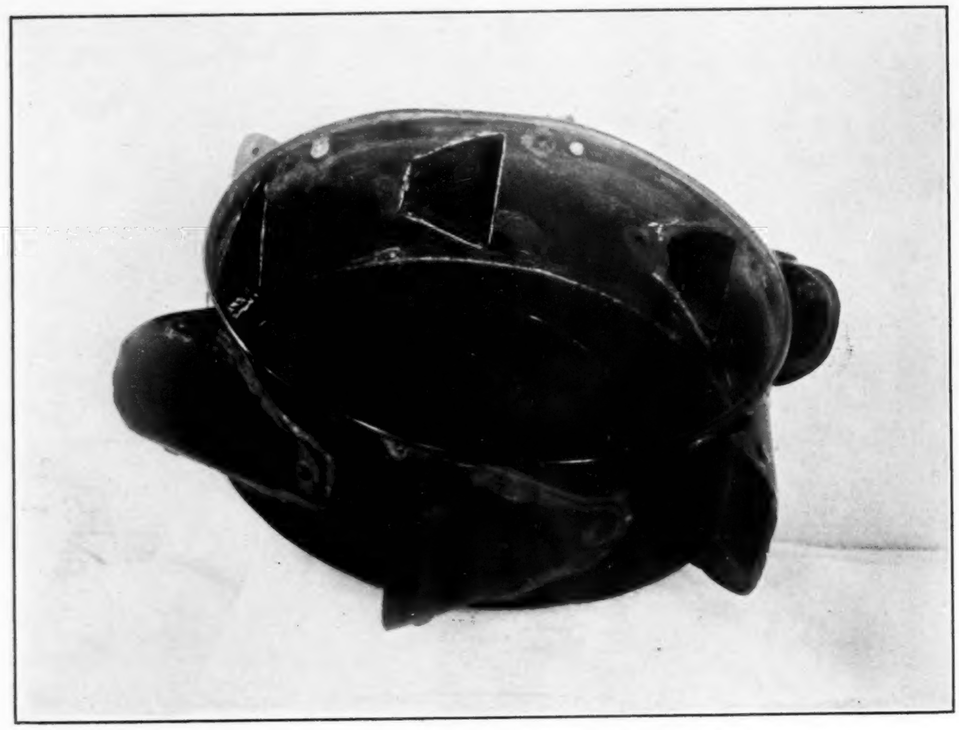


FIGURE 5.—Rotor inverted to show stiffening web at top and lateral heating vents into cups.

FIGURE 6.—Mount Washington Observatory with anemometer in place.

to withstand the force of extremely strong winds with tolerable difficulties. Besides the velocity is much less near a rough rocky surface than in the free air where the anemometer is exposed.

Only slight damage occurred, chiefly to the exposed instruments. A structure supporting a special wind vane, situated at the end of the trestle, partly collapsed and badly smashed a snow gauge. Another wind vane on the trestle was slightly damaged, and the wind vane on the summit tank developed trouble. The observatory building shook considerably under the severe impact, but obviously the heavy covering of rough frost on the exposed east side, and on the roof, must have increased greatly the rigidity of the structure. The delicate pyrheliometer bulb did not suffer the slightest damage, and was found to be covered by a singularly small amount of frost. The telephone line from the summit to the base station was also undamaged.

From 12:35 to 1 p.m. April 12, the one-thirtieth mile contact clicks from the anemometer were broadcast from the observatory's ultra-short (5 m) wave transmitter and were received at the Blue Hill Observatory in Milton, Mass., 142 miles south, by Director C. F. Brooks, who timed the contacts by intervals of 5 seconds. Five samplings of one or two minutes each from 12:37 to 12:55 p.m. showed "true" velocities by 5-second intervals ranging from 108 to 216 mi./hr. The fastest 40 contacts, representing a true mile, came in only 17 seconds, or at a rate of 3½ miles a minute (210 mi./hr.). The mean velocities by whole minutes ranged from 148 to 192 mi./hr., and for the 5½ minutes as a unit, a random sampling of this windy hour, 172 mi./hr.

PART II

THE MOUNT WASHINGTON, N.H., HEATED ANEMOMETER

By D. W. MANN

[Mann Instrument Co., 23 Church Street, Cambridge, Mass.]

As briefly mentioned by Dr. C. F. Brooks in the Engineering News Record of May 10, 1934, an experimental heated anemometer which prevented ice deposits was shown him by Dr. Sverre Pettersson, of the Norwegian Weather Service at Bergen, Norway. Using Dr. Brooks' recollection of this instrument as a basis, and working in cooperation chiefly with Mr. S. P. Fergusson and others at the Blue Hill Observatory at Milton, Mass., the writer first constructed an experimental model which, after a preliminary test in the wind tunnel at the Guggenheim Aeronautical Laboratory of the Massachusetts Institute of Technology was put in use for some months on Mount Washington. Later, in October 1933, the anemometer was given further tests at high-wind speeds at the United States Bureau of Standards. This first model was not entirely satisfactory, but the experience gained indicated clearly where improvements were needed in the design to meet the severe conditions to be expected on Mount Washington.

An anemometer was then designed and built embodying the improvements indicated, and with a few minor changes the instrument has since given satisfactory service.

Figure 3 illustrates the anemometer with the front glass removed to show as clearly as possible the electrical mechanism. The main body consists of a bronze casting with a projecting tube above and a base below. This base is fitted with pipe threads to facilitate mounting the instrument on its roof support.

To the base is permanently attached one-half of an electrical junction box, with which both heating and signal circuits are connected. A vertical shaft carrying the rotor passes through the vertical tubular section of the main body and connects the rotor with reduction gearing located in the central section of the case.

Some of the more important features of the internal mechanism are shown in figure 7. Figure 5 is a photograph of the rotor removed from the instrument and inverted to permit inspection of its interior. The rotor made from hard drawn sheet copper spun into a flat pan 6 inches in diameter and 2 inches deep, has a rolled edge to add to its rigidity. The six fins projecting from its outer edge are, practically, shallow cups. The periphery of the rotor is perforated at each cup to permit passage of heated air into the interior of the cup. The diameter of the rotor over the tips of the opposite cups is 8.25 inches and its weight complete without axis is 22 ounces.

To prevent vibration of the rotor an internal bracing web made from spun copper is fastened rigidly to the rotor at its outer edge, and to a brass hub at the center. This hub permits attachment of the rotor to the main shaft by means of a key engaging a keyway in the latter. A screw into the shaft through the top of the rotor holds it firmly in place. This screw does not project above the top of the rotor, because early experiments showed clearly that no projection could be permitted, frost feathers having formed on even a very short thumb screw.

To enclose the heating coils the lower side of the rotor is provided with a spun copper unit having a tubular center, shown in figure 4. In this figure the rotor is removed and the lower part dropped to show the heating coils. To provide for the complete defrosting of the rotor, the air gap between its tubular part and the column is made relatively small, and auxiliary heat is provided at this point. However, this gap is of necessity large enough to prevent the rotor touching the stationary column even under conditions of maximum vibration.

The heating coils consist of Nichrome wires threaded through holes in a series of transite pillars supported by a flat transite disc secured to the main column. Below this transite assembly is the auxiliary heater which consists of a threaded Isolantite tube, upon which is wound the heating coil for defrosting the air gap below the rotor.

The electrical circuits are so connected that the current used in the rotor heating units passes through the auxiliary gap heater and the amount of heat delivered at the gap is somewhat proportional to that used above. Two windings are provided inside the rotor and leads carried through the junction box so either winding may be used alone, or both together as the maximum current required is about 700 watts. To facilitate warming the cups, and in order to prevent overheating of the top bearing, the heating units are concentrated as near as possible to the outer edge of the rotor, and a tube of heat-insulating material is provided to retard the passage of heat from the heater to the bearing in question.

Figure 4 also shows the plug sockets in the junction box; four small ones for the recording circuits, and three larger ones for the heating circuits. Separate leads are used for all electrical circuits, these being entirely insu-

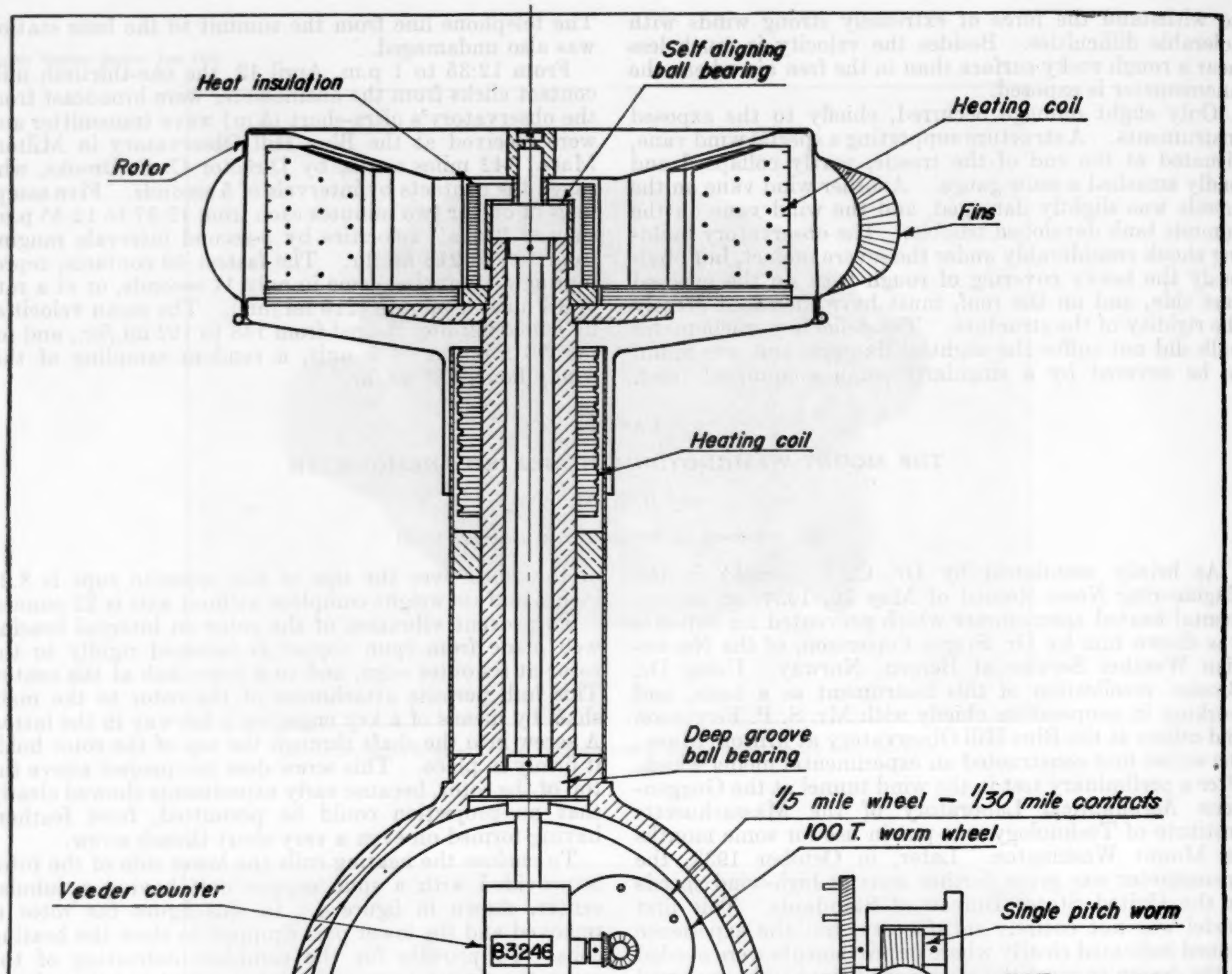


FIGURE 7.—Sectional diagram of anemometer and parts.

lated from the case and from each other. The outer half of the junction box, carrying plugs, is connected by lead-covered cables to the recording apparatus and current supply, and the joint between the two halves sealed with a soft rubber gasket.

The vertical shaft carrying the rotor is provided at the top with an annular ball bearing of the self-alining type, and at the bottom with a deep grove annular ball bearing which also carries the thrust load. A light oil developed by the General Electric Co. for use in watt-hour meters was selected for lubrication. This oil is used because it remains fluid at very low temperatures, as determined by tests by several persons, including the writer, who for a period of several years, worked in cooperation with Mr. B. W. St. Clair of the Lynn works of the General Electric Co., and to whom he is indebted for the oil.

Figure 8 is a schematic diagram, showing the reduction gearing for operating the electrical contacts for recording purposes. A single pitch worm mounted on the lower end of the main vertical shaft engages a 100-tooth worm wheel. Six pins projecting from the face of this wheel operate an electrical contact which gives a signal for each one-thirtieth mile. The shaft on which this 100-tooth wheel is mounted also carries a single-pitch worm which engages a 50-tooth worm wheel on which are mounted 10 pins which give a contact for each mile, 1 mile being recorded for each 500 turns of the rotor. The space between 2 of these 10 pins is made solid to make a long contact for identifying every tenth mile on the record.

Because freezing of the oil film and moisture on the electrical contacts was a source of trouble in the early experiments, a vacuum contact switch, supplied by the Burgess Laboratories, Inc., was selected for the 1-mile recording contact. Since the adoption of this device no trouble whatever has been experienced in their operation under the extreme conditions of temperature encountered.

Uncertainty which the writer felt over a set of anemometer readings made by him during the eclipse of 1932, led to the adoption of a Veeder counter for a visual recorder.

In the early consideration of design it seemed advisable to sacrifice, to some extent, the accuracy at low-wind velocities in order to obtain certainty of operation under the extreme conditions likely to be encountered on Mount Washington. A very recent critical examination of the anemometer, after 14 months of operation, showed no appreciable deterioration.

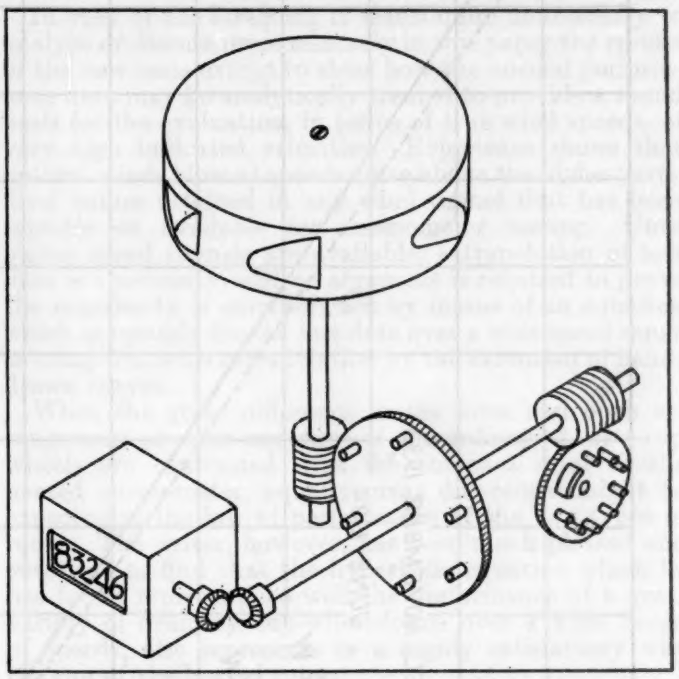


Figure 8.—Schematic view of gear system and Veeder counter. In order to indicate tenth of miles the angular motion is stepped down 2 to 1 inside the counter.

The writer takes this opportunity to acknowledge the kind cooperation of the staff of the Mount Washington Observatory in designing the anemometer, and to thank them for their careful handling of it. He wishes also to thank Mr. H. S. Shaw for maintaining a nightly radiotelephone schedule between Mount Washington and his home, and for his help in many other ways in this project.

Part III

THE CALIBRATION OF THE MOUNT WASHINGTON, N.H., HEATED ANEMOMETER AND THE ANALYSIS OF ITS RECORD OF APRIL 11-12, 1934

By Charles F. Marvin

[Weather Bureau, Washington, July 1934]

When Mr. Mann's perfected anemometer (p. 189) was finished and ready for station use it was first sent to the Bureau of Standards to be tested. Two series of tests of its performance were made during November 1933. One run under a turbulence of about 0.5 percent, comprising a range of velocities from 11.6 miles per hour, just above the starting speed of the rotor, to 143.4 miles per hour, was made in the small 36-inch wind tunnel; the other, under about the same small turbulence, was made in the 54-inch wind tunnel. In view of the relatively small size and compact form of the rotor little or no blocking or other effect depending on the size of the tunnel could be expected, and the agreement between these tests was very close and highly satisfactory.

The calibration-curve representing these tests in the form shown in figure 9–A, as furnished by the United States Bureau of Standards, has been used by the Mount Washington Observatory for the reduction of all the station records.

After the great April 1934 storm and the reading of Mr. Pagliuca's paper on it at the April 1934 meeting of the American Meteorological Society, comments at the Weather Bureau and elsewhere on the accuracy of the reduction of the record led Dr. C. F. Brooks, Director of the Blue Hill Observatory, to send Mr. Pagliuca to Washington in June with the instrument for new tests. The primary object of these tests was to ascertain: (1) Any change since the previous tests in the ordinary performance of the instrument; (2) effects of inclining the axis forward or backward from the vertical; and (3) whether the run of the rotor was much or little affected by turbulence in the test wind stream.

The results of these tests may be stated briefly, in order, as follows:

(1) *Ordinary performance.*—Although neither change by use and exposure nor any alterations or injury that could affect the run of the rotor has been known to occur since the first test, nevertheless the second tests in both

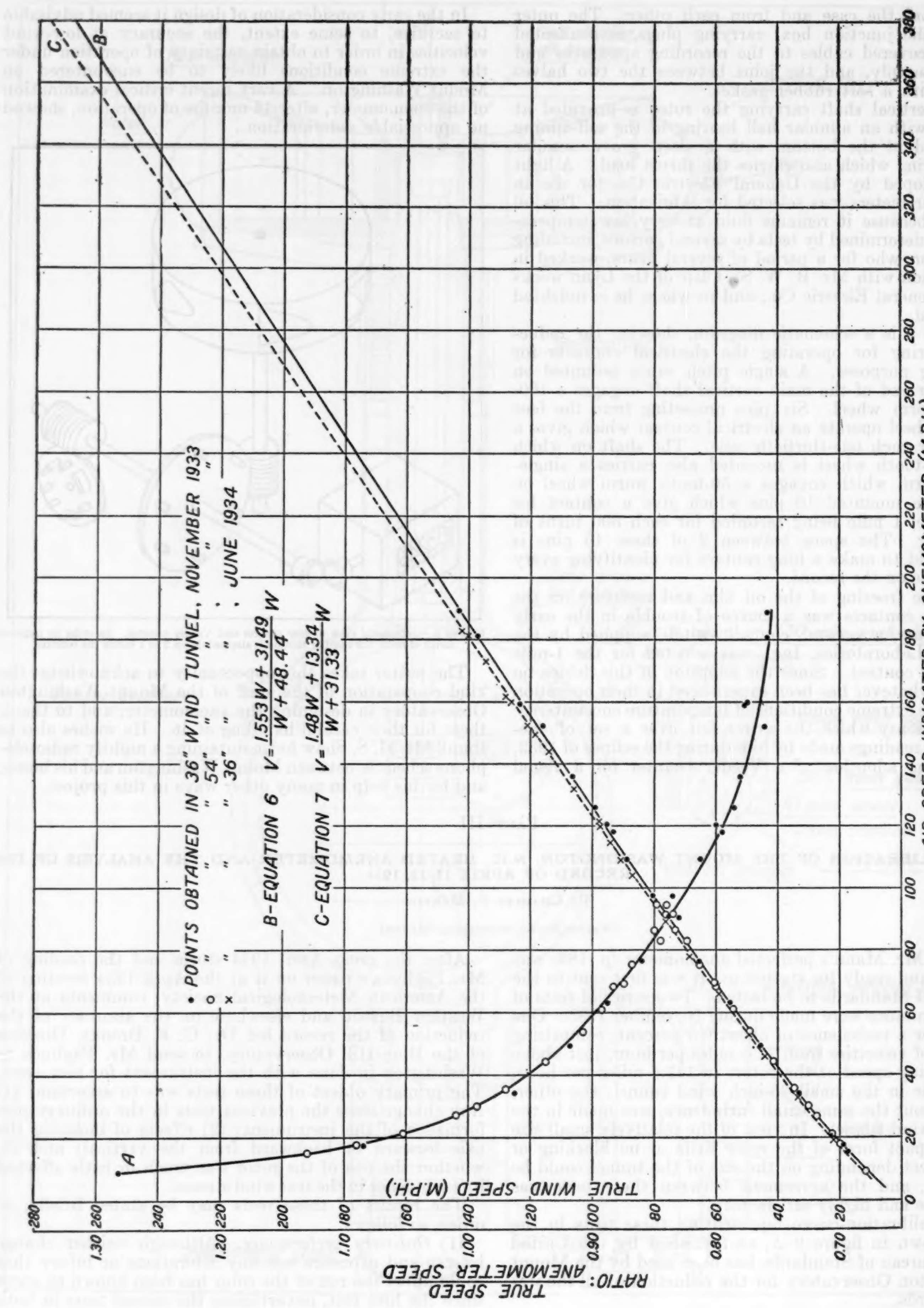


FIGURE 9.—Calibration curves for heated anemometer no. 2. A, Ration curve W/V and original observations dated November 1933 as furnished by Bureau of Standards. B, Hyperbola and same observations as in ratio curve A, Marvin's equation 6. C, Hyperbola by equation 7 of text with observation derived from June test data in 36-inch wind tunnel at the Bureau of Standards.

tunnels indicate that the rotor now seems to run more slowly at all wind speeds and show an as yet unexplained small difference (in general, under 3 percent) between the results of the two tests in the 3-foot (high-speed) wind tunnel. This means that if the past records are corrected on the basis of the new tests the true wind velocities, computed for the record would be somewhat higher than heretofore claimed.

Inasmuch as the original tests in both tunnels agree with entire satisfaction, and further, since we are necessarily dependent upon the tests in the small tunnel for the high velocities, and since, fortunately, the difference between the first and second tests in the small tunnel range under 3 percent, especially at velocities over 40 to 50 miles per hour, true wind speed, it is believed to be both conservative and best to continue to reduce future observations by the original calibration data until further opportunity arises for investigating the cause of the small discrepancies affecting the new tests.

Concerning these discrepancies, it may be remarked that the weight and moment of inertia of this particular rotor are relatively quite high. Moreover, the wind-driving torque is much smaller than for the ordinary 4-inch or 5-inch cup anemometers. These characteristics combine to make this rotor more sensitive to disturbing influences than the conventional cup wheels, notwithstanding that friction has been eliminated quite as fully as possible by high-grade efficient ball bearings. Therefore, the small change in performance may be due to some unnoticed change in the form or condition of the external surfaces of the rotor.

(2) *Effects related to inclination of axis.*—The tests to show the effects of tilting the axis of the rotor forward and backward in the wind stream were all made in the 54-inch tunnel, as were also the several tests with the axis vertical. These tests, of course, are strictly comparable and show that:

(*a*) Tilting the axis forward so that the wind stream impinges downward upon the rotor from above has very little effect as compared with the effects which were found with the wind stream flowing upward against the under side of the rotor. This is an aerodynamic effect and must be independent of possible friction, because the ball-bearing system is correctly designed to permit the rotor to turn with little friction in either case.

(*b*) Tilting the axis forward progressively decreases the run of the rotor until an inclination of about 7° is reached, when the effect apparently is a maximum, after which the relative run increases.

(*c*) At the maximum of effect and for a true wind speed of about 74 miles per hour, the ratio, true divided by indicated wind, was found to be 13 percent greater than when the axis is vertical.

(*d*) Tilting the axis backward speeded up the run of the rotor by an amount which, at true wind speed of about 75 miles per hour, appears to be quite proportional to the angle of tilt.

(*e*) For a tilt of 11⅓° the ratio, true divided by indicated wind, was about 70 percent of its value with the axis vertical.

(*f*) The critical examination of rime formations near the place of exposure of the anemometer at Mount Washington indicates that the air stream driving the rotor is so nearly perpendicular to its axis that no correction for inclination should be applied to the records.

(3) *Effects due to turbulence.*—Tests made in the 54-inch wind tunnel showed that when the turbulence was 2.7 percent the speed of the rotor was only about 1⅓ percent greater than when the turbulence was 0.7 percent. Therefore since the effect of turbulence is so small, and since so little is yet known as to the amount and nature of the so-called "fine-grained turbulence" in the free air, no attempt should be made to take any further account of it.

COMPUTATION AND EXTRAPOLATION OF TEST DATA

In view of the foregoing it seems quite unnecessary to analyze or discuss more minutely in this paper the results of the new tests except to show how the normal performance data may be analytically treated to provide a sound basis for the evaluation, in terms of true wind speeds, of very high indicated velocities. Experience shows that natural winds blow at speeds quite above the highest artificial values attained in any wind tunnel that has been suitable or available for anemometer testing. Until higher speed tunnels are available, extrapolation of test data is a necessity, and no argument is required to prove the superiority of extrapolation by means of an equation which accurately fits the test data over a wide speed range as compared with extrapolation by the extension of hand-drawn curves.

When the great difference in the form and open arrangement of arms and cups of the ordinary 3- or 4-cup wheels are contrasted with the compact rotor of the heated anemometer, equally great differences might be expected in the law of performance of the two types of rotor. The writer, however, has been much pleased and surprised to find that the hyperbolic equation which he has found represents so well the performance of a great variety of ordinary cup-wheel-forms over a wide range of speeds, also represents in a highly satisfactory way the run of the heated rotor.

In compliance with requests of Mr. Pagliuca to do so for the benefit of the observatory staff, the derivation of the parameters of the hyperbolic equation from the original test data on the no. 2 anemometer is presented with sufficient fullness below.

For reasons given more fully in the article in the MONTHLY WEATHER REVIEW April 1934, page 116, the 34 original test values have been combined into 10 group means of true wind, W, and indicated wind, V, on the basis of 500 rotor turns per indicated mile. Values of N, free from small arithmetical inaccuracies, were then computed by the equation $N=500\ \Sigma V \div \Sigma W$ in which ΣV and ΣW are the sums from which the group means are computed. Table 1 gives the 10 group mean values of W and N. These constitute the 10 observation equations by means of which the unknown parameters, a, b, and f of the full hyperbolic equation, $f+Wb+Na+NW=0$ are to be evaluated.

TABLE 1.—*Group mean observations and derived data from original tests made in November 1933, by the Bureau of Standards on Mount Washington heated anemometer no. 2*

	Observations		Derived data				
	W	N	NW	W^2	N^2	NW^2	N^2W
	14.3	421	6,020.3	204.49	177,241	86,090.29	2,534,546.3
	20.2	466	9,574.8	408.04	224,676	193,410.96	4,538,455.2
	31.2	509	15,880.8	973.44	259,081	495,480.96	8,083,327.2
	45.4	544					
	57.9	566					
	68.4	586					
	78.0	598					
	94.4	627					
	117.3	647					
	140.2	660					
Sums	667.3	5,624	403,123.6	60,088.79	3,218,108	37,632,990.90	245,655,263.2

It is scarcely necessary to remark that every digit in table 1 must be scrupulously exact, and that all digits must be retained in computing the derived data. Unnecessary digits should be dropped at the end of, not during, the analysis.

First compute the values of NW for which a modern calculating machine is best. The values of W^2 and N^2 are next entered from tables of squares, or otherwise. Then form values of NW^2 and $N^2 W$ by multiplying W^2 by N and then N^2 by W. When the values are all entered they should be rigorously checked, thus: multiply NW first by W, then by N. These operations completely check every value of the derived data. All that then remains to be done is to form the sums of each of the columns. By the least-square methods these sums furnish the coefficients for the three so-called "normal" equations whose solution gives the desired values of the three parameters.

The normal equations are:

$$
\begin{array}{llllll}
\text{For} & f, & 10f & +Wb & +Na & +NW=0 \\
\text{For} & b, & Wf & +W^2b & +NWa & +NW^2=0 \\
\text{For} & a, & Nf & +NWb & +N^2a & +N^2W=0
\end{array}
$$

Supplying the numerical coefficients from the sums in table 1 these become,

$$
\begin{array}{llll}
10.0f+667.30b & +5{,}624.0a & +403{,}123.6 & =0 \\
667.3f+60{,}088.79b & +403{,}123.6a & +37{,}632{,}990.9 & =0 \\
5{,}624.0f+403{,}123.60b & +3{,}218{,}108.0a & +245{,}655{,}263.2 & =0
\end{array}
$$

Dividing each of these equations by the coefficient of f therein gives:

$$
\begin{array}{llll}
f+66.7300b & +562.400a & +40{,}312.4=0 & (1) \\
f+90.0476b & +604.111a & +56{,}395.9=0 & (2) \\
f+71.6792b & +572.210a & +43{,}679.8=0 & (3)
\end{array}
$$

Subtracting (1) from (2) and (3) gives

$$
\begin{array}{lll}
23.3176b+41.711a & +16{,}083.5=0 \\
4.9492b+9.810a & +3{,}367.4\ =0
\end{array}
$$

Dividing by the coefficients of b gives

$$
\begin{array}{lll}
b+1.78882a & +689.757=0 & (4) \\
b+1.98214a & +680.393=0 & \\
\hline
.19332a & -\quad 9.364=0 & (5) \\
a=+48.4378 & &
\end{array}
$$

Substituting a in equations 4 and 5 gives the folowing two values of b: $=-776.403$ and -776.403. The agreement is perfect. Substituting a and b in equations 1, 2, and 3 gives three values of $f=-15{,}744.4$, $-15{,}744.5$ and $-15{,}744.5$. The nearly perfect agreement here also indicates that there was no arithmetical error in the calculations, and the final equation solved for N becomes

$$N=\frac{776.4W+15{,}744}{W+48.44}$$

The relation $NW=500V$ gives

$$V=\frac{1.553W+31.49}{W+48.44}W \qquad (6)$$

Equation 6[1] is believed to be the most refined evaluation of the original test data from the runs made in the two wind tunnels in November of 1933. This equation, or a table of values of true and indicated speed based thereon, is recommended by the writer for use in correcting all Mount Washington wind records derived by use of the heated anemometer no. 2. The corresponding equation derived from the recent June tests in the 36-inch tunnel is

$$V=\frac{1.48W+13.34}{W+31.33}W \qquad (7)$$

It is important to show how very small are the residuals between the observed and calculated values by these two equations. They are given in table 2.

TABLE 2.—*The observed and calculated values of V for the two sets of group mean observations representing tests at the Bureau of Standards on the Mount Washington heated anemometer no. 2.*

Tests in November 1933, in both tunnels. Equation 6				Tests in June 1934, in 36-inch tunnel only. Equation 7			
W	V_o	V_c	V_c-V_o	W	V_o	V_c	V_c-V_o
14.3	12.00	12.23	+.14	22.3	19.20	19.27	+0.07
20.2	18.86	18.50	−.36	38.9	39.60	39.27	−.33
31.2	31.76	31.32	−.44	54.2	59.42	59.28	−.14
45.4	49.32	49.34	+.02	72.4	83.76	84.09	+.33
57.9	65.49	66.10	+.61	88.9	106.46	107.14	+.68
68.4	80.19	80.61	+.42	96.5	118.53	117.88	+.65
78.0	93.43	94.14	+.71	110.4	137.77	137.65	−.12
94.4	118.29	117.69	−.60	119.9	150.97	151.25	+.28
117.3	151.71	151.19	−.52	127.1	160.98	161.60	+.62
140.2	185.00	185.20	+.20	134.6	172.80	172.40	−.40
				141.2	182.06	181.93	−.13

The curve figure 9–B, plotted from accurately calculated values of equation 6 furnishes an excellent graphic extension of test data by which extrapolated corrections of extreme wind records may safely be made.

ANALYSIS OF WIND VELOCITY RECORD

Figure 2 is a photographic reproduction of the velocity portion of the original automatic wind velocity record from 12:10 p.m., April 11, to 3:05 p.m. April 12, 1934. This picture is presented in two parts in order to preserve the full scale (15 inches between marginal lines).

To make the record of single miles readily legible when the velocity is high, the miles of wind movement are recorded by the so-called zig-zag mechanism of the Weather Bureau multiple register. Each step in the zig-zag path which in the ordinary usage represents a rainfall of one-hundredth of an inch, or that the sun was shining at the time, now represents one mile of indicated wind movement, 500 cup turns. From crest to crest, or hollow to hollow of the trace, there are always exactly 10 steps. However, owing to the use of a so-called "bridge" pin (see fig. 7) for the purpose of automatically recording miles in groups of ten, the actual wind movement from crest to crest, or hollow to hollow, of the record, is always 11, not 10, miles. The passage of the bridge pin is clearly apparent in records of light and moderate winds, but can be discerned only with difficulty at some places in the present record.

Mr. Pagliuca has already stated on page 187 the general features of this splendid record of such a remarkable wind. The chief object of the present analysis is to critically evaluate the maximum wind travel in 5 minutes which occurred shortly after noon of April 12 in the place indicated by the letter M. Emphasis is placed on the maximum travel in 5 minutes, because it is standard practice at regular Weather Bureau stations to record this datum as a sort of gust velocity, although greater

[1] Equations 6 and 7 when solved for W require a complicated radical expression which cannot be computed accurately except with great difficulty. Values of V for exact integral values of W are accurately and rapidly computed to several decimal places if necessary from equations like 6, from which tables of true and indicated velocities may be computed by transposition and interpolation.

gusts of shorter duration are also recognized. The accurate timing of single miles in such a record as that shown is, of course impossible, and the irregularity in the record caused by the registration of the passage of the "bridge" pin further limits refined measurements of the record simply to timing as accurately as possible the crests and hollows during the period of extreme velocities. In order to employ a method which would single out the greatest wind travel in a 5-minute period and which at the same time would be free from any personal bias, the writer chose the following: A standard millimeter scale was clamped down on a clear photographic copy of the record. The zero was placed at the noon line, and the scale alined parallel to the slope of the record, then with the aid of a piece of celluloid engraved with a fine transverse reference line, the scale readings given in table 3 were made of several crests and hollows before and after the place of maximum travel.

TABLE 3.—*Millimeter scale readings on crests and hollows of a portion of zig-zag wind trace like fig. 2 from noon to 12:30 p.m. Apr. 12*

Crest N°	Scale reading:	Diff. single 11 miles	Sums 22 miles	Hollow N°	Scale	Diff. single 11 miles	Sums 22 miles
0	1.9	----------	----------	.5	3.6	----------	----------
1	5.1	3.2	----------	1.5	6.6	3.0	----------
2	8.3	3.2	6.4	2.5	9.5	2.9	5.9
3	11.1	2.8	6.0	3.5	12.7	3.2	6.1
4	14.1	3.0	5.8	4.5	16.0	3.3	6.5
5	17.3	3.2	6.2	5.5	19.2	3.2	6.5
6	20.4	3.1	6.3	6.5	22.0	2.8	6.0
7	23.0	2.6	5.7	7.5	24.5	2.5	5.3
8	25.7	2.7	5.3	8.5	27.2	2.7	5.2
9	28.8	3.1	5.8	9.5	30.1	2.9	5.6
10	31.9	3.1	6.2	10.5	33.1	3.0	5.9
11	34.5	2.6	5.7	11.5	36.0	2.9	5.9
12	37.5	3.0	5.6	12.5	39.1	3.1	6.0
13	40.7	3.2	6.2	13.5	42.0	2.9	6.0
14	43.5	2.8	6.0	14.5	45.0	3.0	5.9
15	46.9	3.4	6.2	15.5	48.0	3.0	6.0

1 hour=65.1 mm. 5m=5.4 mm.

It is clear from the table that at the time of the maximum there was a sustained high movement represented by at least four double 22-mile groups having a time space ranging from 5.2, 5.3 up to 5.7 mm. Since a space of 5.4 mm. represents a time interval of 5 minutes, the maximum travel in 5 minutes must have ranged between at least 20.9 and at most 22.8 indicated miles, that is, 251 or 274 indicated miles per hour. By the November tests of 1933 (equation 6) these indicated speeds correspond to true hourly speeds of 184 and 199 miles per hour. By the June 1934 tests in the 3-foot tunnel (equation 7) the corresponding hourly movements are slightly higher, that is, 187 and 204 miles.

In the case of the still higher gusts timed by stopwatch, permitting reading time to hundredths of seconds, it is stated the shortest elapsed time was 1.17 seconds for an indicated travel of one-tenth mile, that is, 308 miles hourly movement, which corresponds to a true wind of 221 miles per hour by the November 1933 calibration, and 225 miles by the June 1934 test.

Great confidence is justified in the verity of these results, especially the 5-minute travel, because of the perfect character of the automatic record, the sustained movement during the maximum, the excellent fit of the hyperbolic equation to the test observations, and finally, the sound character of the extrapolation of corrections to extreme wind speeds.

FURTHER CONCLUSIONS FROM ADDITIONAL OBSERVATIONS IN THE FREE AIR OVER SAN DIEGO, CALIF.

By DEAN BLAKE

[Weather Bureau, San Diego, Calif., 1934]

Because of their importance to aviation, their domination of climatic conditions in the regions affected, and the challenge they present, the fogs and overcast skies, and the concomitant temperature inversions that occur along the California coast during the summer, are the subject of considerable discussion and speculation. In spite of what has been written already, there remains a fruitful field open to research and investigation. Writers, too, are far from any sort of agreement as to their causes, and most of the conclusions that have been reached are based upon an insufficient amount of data.

This paper is in the nature of a supplementary discussion to others that have appeared, and is offered as an aid in the clearing up of some disputed points, by the presentation of additional data, made available through the courtesy of the aerological office at the Naval Air Station, San Diego, Calif. In it attempts are also made to couple various phases of the phenomena with the results of recent investigations, particularly with the findings from free air observations. With the accumulation of data, and the attainment of greater accuracy in aerological records, due largely to changes in technique, and an improvement in the aerographs in use, it has become possible to analyze many more statistics, and to draw much more accurate conclusions.

Several quite complete descriptions of the inversion and its attendant cloud stratum have been published, Byers, (1) and Anderson, (2) in particular, going into detail. All writers agree that it is a summer phenomenon limited to the littoral regions. It is characterized by the regular occurence of overcast skies during the greater part of the night and in the early morning; a decrease in temperature and an increase in relative humidity to the top of a relatively thin layer of air; and an increase in temperature and a rapid decrease in relative humidity for several hundred meters beyond, after which the normal lapse rate is approximated, and the humidity remains fairly constant but low.

The inland invasion of the vapor-laden stratum depends upon the elevation of the land contiguous to the ocean. Where a mountain range parallels the immediate coast without an opening, an effective barrier is offered, but where there are no elevations in its way, it penetrates well into the interior. Airways reports in San Diego County show that low clouds or fogs are prevalent in the early morning hours at least 40 miles inland, if there are no obstacles to prevent the sea breeze from carrying the moist air that far, but where mountains with an elevation of several thousand feet skirt the shore line, they are normally confined to the coastal areas.

The seaward extent is not definitely known, but Anderson states that it seems safe to assume that the stratus bank is usually unbroken for a distance of 200 to 300 miles.

There is ample proof that the cloud layer with an inversion above appears in the late spring or early summer, coincidentally with warm weather and the attendant thermal semi-permanent low pressure area over the Far Western interior. This year, for example, record-breaking high temperatures were recorded in the interior of southern California and the valleys of Arizona, as early as March, and, at the same time, low stratus developed along the southern coast, where the aerograms showed the anticipated rise in temperature above. Normally, though, no regularity of inversion conditions can be expected until June. May records show less than 50 percent of the days with inversions; June 76 percent; July 93 percent; and August 92 percent. In September the seasonal decrease in the number begins again. During several of the Julys and Augusts under consideration, every aerogram was of the inversion type.

Several explanations have been proposed. The first, by Thomas (**3**) in 1925, was to the effect that a form of convective circulation was in operation; a lower, moister layer of air coming from the ocean, with a higher, warmer counter-current finding its way westward across the mountains from the desert beyond, where it was supposed to have its origin in the intense heat. This idea still is held by many fliers.

Blake, with the help of Bowie (**4**) next offered the concept of a relatively cool stratum of moist air from the ocean overtopped by warmer air of continental origin brought in from great distances. In the paper an analysis was made of the data available up to that time.

Sometime later, Byers (**1**) expressed the conviction that "it is simply a case of cool, moist air making inroads into the warm air of the land", and "the warm air aloft is not brought in from the interior either directly or indirectly, but is the normal condition in the area."

Not content with the other explanations, Lieutenant Anderson (**2**) ascribed the formation of the cloud stratum to the action of turbulence. He asserts in his paper that the water of the Pacific ocean everywhere is warmer than at any given point along California. Thus, as the air moves toward the land, it must pass over colder and colder water, and in its passage the surface layers become cooled. Due to friction between the air and the water, the air becomes turbulent, and through energy supplied by the wind, eddies are formed which mix the colder surface air with the warmer air above. In this way the temperature of the stratum decreases with altitude up to the base of the inversion, the height of which depends upon the wind force, temperature and humidity.

Of the causes of the inversion, he is of the opinion that any mass of air approaching the coast from a considerable distance at sea must develop an inversion. If clouds do not develop, the lapse rate of the air near the coast would be approximately equal to the dry adiabatic up to the top of the stratum, but above that point the temperature would increase, with the maximum at some point, say, 1,000 feet higher. Thus, in Anderson's opinion, the inversion is a sea condition caused by the cold water along the coast.

As these deductions are based on the premise that practically all of the air over the coastal region, regardless of its altitude, comes from the ocean, it will profit us to look into the accuracy of the data from which they have been drawn.

It is unfortunate that both Byers and Anderson laid so much stress on the summary of pilot-balloon soundings for June, July, and August, 1924–27, published in the writer's article previously referred to. Table 1, which is based on more recent data, is offered for consideration, and shows considerable variation from the summarization of the earlier period. It presents the number of times at the San Diego Airport Station, during July and August 1933 that the wind was observed from each of the 16 directions at elevations to 10,000 meters. In it, the sea breeze (SW. to NNW.) is found to prevail to 1,000 meters, but above this elevation there is a backing toward the directions between the south and the east, with the change from the westerly quadrant to the southerly quite abrupt. A significant feature is that even in the highest altitudes no return to the western sector is apparent.

That the results in the table are in no way abnormal, is borne out by the wind roses, for San Diego and Los Angeles, on the Pilot Chart of the Upper Air for the North Pacific Ocean, for July and August, which graphically present over a period of several years at the 10,000-foot level (3,000 meters), the same preponderance of directions from land sources.

If a further check of the accuracy of table 1 is needed, it is presented in table 2, the movements of the upper and intermediate clouds at San Diego during July and August in the last 7 years. The omission of alto-stratus clouds from the table is due to their rare occurrence.

Granting its prevalency, the source of this upper-air movement is not hard to find. In a convincing paper by T. R. Reed, in the MONTHLY WEATHER REVIEW for November 1933 (**5**) the existence of an anticyclonic circulation, in the upper levels over southwestern United States and northern Mexico during the warm season, was conclusively demonstrated, its western rim embracing the California coast. This paper leaves little doubt that, as a rule, winds aloft over San Diego, coming from directions between the east and southwest during the summer months, belong to this great, upper wind system that covers all of the southwestern portion of the north American continent, and that, in their broad, clockwise movement, may have traversed the Mexican highlands, but in any event have been warmed by subsidence en route.

A day-to-day study of the aerograms, received in the San Diego office from the Naval Air Station, soon convinced us that some hastily formed, but generally accepted, conclusions were not substantiated, so a tabulation and analysis was made of all observations with inversions of temperature in June, July, and August during the 5 years, 1929–33. A summarization of these data is found in tables 3 to 6.

In passing, it may be remarked that it always has been assumed that the top of the cold moist layer coincides with the point of lowest temperature and highest relative humidity, regardless of whether or not clouds are visible. While some discrepancies occasionally appear between the elevations observed and those indicated by the aerograph traces, they are not too large to be ascribed to instrumental error or lag.

THE COLD MOIST STRATUM

In the consideration of the tables and othere data at hand, several points are found worthy of enumeration.

1. Published opinions to the contrary, notwithstanding, the top of the stratum does not remain at the same height during any given occurrence, but is subject to

marked changes in the 24 hours. Table 3 conclusively shows that it is lowest in the afternoon and highest in the morning, with an average change in elevation of 102 meters (335 feet). That this variation is not an error resulting from the use of a mean derived from separate and differing sets of readings, is verified by the results given in table 4, data for days with two aerograms, one at 8 a.m., and one at 1 p.m. The agreement between the two sets is too close to be accidental. Furthermore, this change in the height of the top of the stratum has been found to occur on days completely overcast, on two occasions the afternoon showing a drop of over 300 meters (1,100 feet).

It may be remarked here that assertions are frequently but loosely made, that if the height of the top of the moist layer has been established at one point in southern California, say at Mount Wilson, that it will have the same elevation everywhere else in the district. This is not so. Careful observations by Army pilots show a difference of several hundred meters between the coast in the Los Angeles area and the San Fernando Valley, a gradual increase taking place with increase of distance inland.

2. The thickness of the layer changes considerably from day to day, and, as the top rises or falls there is a corresponding rise or fall in the ceiling below a large part of the time. In other words, a lowering of the ceiling usually is accompanied by a dropping of the top of the cloud. Surface fogs generally occur when the elevation of the top is below the average thickness of the stratum. From this we are convinced that one of the most promising methods of solving the appearance of summer fogs at the surface, is to determine the controlling factors in the height of the cold moist layer.

3. The height of the stratum tends to follow in a converse manner the mean temperature curve for valley stations in San Diego County; that is, it is lowest when the temperature is highest. This is shown graphically in figure 1. The same correspondence is noted with the same curve drawn for desert stations to the east, but is less pronounced.

4. Cloud ceilings at coastal stations almost invariably rise just before the sky clears. Dissipation, as a rule, first begins inland, and works its way to the coast, where a cloud bank can be seen at sea during the balance of the day. After sunset, clouds form again quite suddenly, and, as the formation gradually progresses toward the interior, the ceiling drops slowly, reaching the minimum in the hours around sunrise. It is most significant that clouds often appear several miles inland before they begin to overspread the littoral. The statement by Varney (*6*) that dissipation of the "high fog" proceeds very largely from the top downward in the piedmont littoral of Los Angeles, is not in accord with observations at San Diego.

5. The moist stratum is rendered visible (when clouds are not present) by a haze layer which extends to the ground. Above this, smoke and dust do not penetrate, and visibility, normally, is unlimited. On numerous occasions, clouds actually have been observed in the process of formation at the top of the haze. Invariably they built downward, and in their disappearance invariably began to dissolve at the bottom. That they occasionally grow upward and dissipate downward is probable, but a "burning off" from the top to the bottom has never been witnessed by the personnel at the San Diego offices.

We believe that the conclusions reached by Bowie in his paper "The Summer Nighttime Clouds of the Santa Clara Valley, Calif. (**7**) cover and explain the formation of the stratus clouds of summer at San Diego as well as in the San Francisco Bay region.[1]

That turbulence is found in the moist air is evident. The cloud shows it, aviators experience it, and the uneven top of the stratum verifies its existence. But the assumption that such turbulence is the effect of advective processes is refuted by the fact that the turbulence reaches its maximum after horizontal wind movement has practically ceased. By the tables the top of the stratum is proved to be actually several hundred feet lower during the warmest and windiest hours than it is during the quiet morning hours. Furthermore, turbulence which results from advection in a stable air mass cannot produce an unstable lapse rate, whereas radiation from the superior surface of such a mass not only can but continually does, with turbulence as a consistent and inevitable consequence.

It may be well here to point out that the role played by advective turbulence in the formation of advection fog, found at all seasons on the California coast, is fully recognized, and not minimized in the least. It is further realized that fogs of this type spread over the land at times. However, in this paper we are concerned solely with the so-called "high fog", the formation of which is believed to be by nocturnal radiation from the top of the cold stratum, with the growth of the cloud taking place downward.

We cannot believe, furthermore, that a cloud layer which penetrates, and upon occasion actually forms many miles inland, depends entirely upon the action of wind and wave for its origin. The very fact that its dissipation is from the bottom up, and its formation from the top down, should eliminate any explanation that involves the initial cooling at or near ground level.

Surface turbulence, if further argument is needed, would tend to prevent stratification rather than give rise to it. Under no circumstances could it cause a mass of air to rise to a uniform level over an area of several hundred square miles, particularly when surface elevations vary greatly, and different temperature and pressure gradients, moisture content, and wind velocities obtain.

THE INVERSION LAYER

A brief description of the salient features of the inversion layer remains to be given, so, in addition to the data offered in tables 5 and 6, the following summing up is presented.

1. The temperature inversion persists both day and night, but there is no regular diurnal maximum and minimum temperature. The mean change between the

[1] The essence of Bowie's theory it found in the following quotation taken verbatim from the paper in question: "It is known that air rich in water vapor is selectively highly absorptive of terrestrial long-wave-length radiation; and being a good absorber it also is a good radiator in the same spectral region, in fact as good, nearly as a black body. Conversely, dry, clear air is diathermanous to terrestrial of long-wave-length radiation and therefore in that region a nonradiator, and its temperature subject to change only by work done by it or upon it. Hence at night the stratum of marine air rich in water vapor cools radiationally while the stratum of dry air above it remains at a constant temperature or, at most, loses its heat very slowly. * * * When this situation exists the excess of outgoing over incoming radiation is at its maximum at the upper surface of the bay of marine air, and sometime during the night the cooling thus caused reaches the dew point, condensation starts and cloud forms. It does not necessarily follow that the dew point is reached first at the upper surface of the humid air; it may be at some intermediate altitude between this surface and the bottom. When the dew point is reached at the upper surface first, the growth of the cloud is downward; whereas when it is reached first at an intermediate altitude the growth of the cloud is both upward and downward. Ultimately the cooling throughout the marine air, from a maximum at its upper surface downward to a minimum at its bottom, may result in the lapse rate exceeding the adiabatic, when there will follow convection and turbulence that would cause a pilot passing through or under the cloud to experience bumpiness. This convective turbulence increases the rapidity of cloud formation. The descending currents, the counterpart of the ascending currents in the convective process, are not heated at the adiabatic rate for dry air, for in them there is loss of heat by evaporation, the equivalent of that gain by condensation in the ascending current. As the cooling proceeds the thickness of the cloud increases and at times the entire mass of marine air is filled with cloud from top to bottom."

morning and afternoon, as shown in table 6, is only 0.2° C. with the afternoon readings higher only 55 percent of the time. In August, mornings were actually warmer than afternoons.

2. The height of the maximum inversion varies from morning to afternoon and from day to day, and the change in elevation, while independent of the upper surface of the cold stratum, is similar in that it is usually lower in the afternoon than in the morning.

3. Apparently there is no relation between wind direction and the highest temperature found aloft; the winds are generally light and variable.

4. Warm weather at ground stations is often accompanied by a rise in temperature in the upper air at the same time unless convectional overturning results, and the inversion is displaced. However, a warm summer at the surface does not signify a similar condition aloft. For example, in the records for San Diego County, the summer of 1931 was abnormally warm, yet inversion temperatures averaged the lowest of the five summers under consideration.

5. Temperatures in the upper air have not proved to be as high as reputed. Above 90° F. was recorded twice only in the last five summers, and maxima over 85° F. were registered only infrequently. The absolute highest for the period was 92° F. on July 26, 1933; also the warmest day of the month at surface stations.

From these data and arguments, we are convinced that the cold stratum is of marine origin, and the inversion is of continental origin, the direct cause of high temperatures aloft usually being subsidence of air brought in by the thermal high-level anticyclone. The two strata are fundamentally different, and like a layer of oil on a layer of water—they will not mix.[2]

What may be taken as visible proof of the immiscibleness of the two strata was witnessed recently near Los Angeles. Black smoke from a burning oil well rose as a huge dome several hundred feet into the inversion layer, but was unable to penetrate it, the smoke surrounding the dome settling along and outlining the top of the cold stratum. Directly over the fire, however, thermal convection was of sufficient strength to make the dome of smoke-filled air. The whole formation appeared as though an invisible lid was establishing definite ascensional limits.

Sailplanes and gliders, according to pilots, cannot rise beyond the upper surface of the marine air. Lange (**8**) explains this by the principle that "temperature inversions resist the vertical air exchange, and generally retard the vertical velocities completely."

The inversion problem is more than local. In his paper on fog and haze, Willett, (**9**) on page 448, remarks that Georgii and many others have pointed out that inversions commonly found above "high fog" are the surfaces of subsidence in anticyclones. Now that logical sources for the descending currents have been discovered, the explanation of the phenomena on the California coast is apparent.

[2] On the margin of the manuscript, T. R. Reed made the following annotation: "Any air mass, which has undergone subsidence, might conceivably supply the source. All meteorologists agree that there is subsidence in the antitrades, so it would not be hard to imagine at times a marked settling of tropical air anywhere in these latitudes, perhaps accentuated in this vicinity by the cold waters found off our coast. Furthermore, it is conceivable that air in its vast clockwise trajectory around the Pacific high area may have its source far to the south, and reach the California coast as a relatively warm northwest or west wind, which has become dry and has gained additional heat in its descent."

How else, except by dynamically heated descending air, are we able to account for the excessively low relative humidity readings that occurred in June 1932 over San Diego, when the aerograph recorded 0 percent at all levels from 8,000 to 11,000 feet with westerly winds prevailing? (**10**).

As a rule winds in the lower levels of the inversion are from the direction of the ocean. This, to many, is a serious objection to the subsidence theory. An analogous situation and a logical explanation may be cited in the weather at San Diego where high temperatures generally occur with winds coming directly from the water; yet the relative humidity may be extremely low, and strong east and northeast winds may be blowing at the 300- or 500-meter level. It is not improbable that a similar condition obtains in the inversion canopy, where light east to southwest winds prevail above the 2,000-meter plane, and the sea breeze in variable depths below. Even if winds are from the ocean at the point of maximum inversion, they still may convey the hot dry air of the 4,000- or 4,500-meter levels.

Byer's suggestion that warm air of the inversion layer is not brought in either from the interior or the ocean, but is a normal condition in the air, yet remains to be considered. This explanation must be dismissed on the grounds that no diurnal change is apparent, and the highest daily readings are recorded in the morning almost as often as the afternoon. If temperatures in this layer were normal, as contended, the normal lapse rate above the moist stratum would be closely approximated because the impenetrability of the inversion layer precludes mixing from below to any degree. Moreover, temperatures in the inversion layer have been found to be independent of terrestrial radiation, and are not affected by high or intermediate cloudiness that materially lowers surface readings.

Several fellow workers, whose assistance is gratefully acknowledged here, raised a query as to why the temperature peak is so far above the lower stratum. In the tables submitted its average height is 1,248 meters (4,100 feet), which places it 746 meters (2,450 feet) above the cold stratum. If our deductions have been correct, the highest readings should occur at the level of maximum subsidence some distance above the base of the inversion, leaving an air mass of varying thickness which would tend to damp out descent in the lower levels of the inversion. It is found at the most logical place. The source of the variation in height, temperature and humidity of the whole upper layer is found in the strength, depth, origin, and water vapor content of the air stream from which its very existence is obtained.

Our conclusions, then, briefly summed up are as follows:

1. The underlying cool moist stratum is of maritime origin. Clouds form along the top by radiation, usually in the early evening, and as night advances, build downward. In the morning, dissipation begins at the bottom and works upward.

2. The overlying warm dry stratum, known as the inversion layer, is usually the result of subsidence of air from the interior of the continent, brought to the California coast by the high-level anticyclone, centered over the heated regions to the eastward.

TABLE 1.—*Summary of pilot-balloon ascensions at San Diego, Calif., during July and August 1933. Observations at 3:30 p.m., P.S.T.*

[Meters]

Direction	Surface	250	500	750	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	6,000	7,000	8,000	9,000	10,000
N	----	----	1	1	3	2	1	3	2	1	1	----	----	----	----	----	----	----
NNE	----	----	1	----	----	----	1	----	1	----	----	----	----	----	----	----	----	----
NE	----	----	1	1	----	2	3	----	----	1	----	----	2	2	----	----	1	1
ENE	----	----	----	----	----	1	2	4	1	2	2	1	1	1	1	1	1	1
E	----	----	----	1	----	----	3	2	5	4	5	5	6	3	3	4	1	----
ESE	----	----	----	1	----	1	3	5	5	3	2	2	----	1	3	1	1	2
SE	----	1	----	2	1	----	5	7	6	7	3	4	3	3	----	----	1	----
SSE	----	1	----	6	3	8	5	6	3	5	5	4	6	1	1	1	----	----
S	7	1	8	5	8	6	6	5	5	6	8	6	4	5	1	----	2	1
SSW	5	7	5	2	4	1	2	5	8	3	4	4	6	5	2	----	----	----
SW	7	10	5	3	1	5	5	3	2	5	3	5	1	1	2	4	2	----
WSW	4	1	4	3	2	5	3	1	4	3	6	2	3	3	1	1	1	1
W	13	8	7	3	5	3	3	4	1	2	4	6	4	2	----	----	----	----
WNW	16	18	8	6	6	3	1	2	1	1	----	----	----	2	----	----	----	----
NW	10	14	14	11	13	7	3	----	1	1	----	1	----	----	----	1	1	1
NNW	----	1	6	10	7	6	4	1	----	----	----	----	3	1	----	----	----	----
CALM	----	----	----	----	----	1	----	----	1	----	----	----	----	----	----	----	----	----

NOTE.—Soundings during June were made at 8:30 p.m., P.S.T., usually after clouds had formed, and few reached a greater height than 1,500 meters, and none over 5,000 meters.

TABLE 2.—*Percentage of times upper and intermediate clouds were recorded from various directions at San Diego, Calif., during July and August 1927–33*

	Ci.	Ci. St.	Ci. Cu.	A. Cu.
N	1	1	0	0
NE	2	4	2	3
E	15	27	18	25
SE	31	42	46	49
S	18	18	25	15
SW	15	0	2	4
W	7	2	0	0
NW	1	0	0	0
CALM	10	7	7	4
Number of observations	107	45	44	194

NOTE.—Those reported calm were usually on the southern or eastern horizon, and were too distant for the direction to be determined.

TABLE 3.—*Average height, mean temperature, and relative humidity at the top of the cold stratum during June, July, and August 1929–33, inclusive, for all observations*

Month	Number		Average height		Temperature		Relative humidity	
	A.m.	P.m.	A.m.	P.m.	A.m.	P.m.	A.m.	P.m.
			Meter	*Meters*	*°C.*	*°C.*	*Percent*	*Percent*
June	72	45	641	529	13.7	14.1	88	85
July	96	60	514	457	17.2	17.7	90	85
August	103	63	496	413	17.9	19.3	90	75
Total	271	168						
Average			545	460	16.5	17.2	90	83

TABLE 4.—*Average height, mean temperature and relative humidity at the top of the cold stratum during June, July, and August 1929–33, inclusive. For a.m. and p.m. observations made the same day.*

Month	Number	Average height		Temperature		Relative humidity	
		A.m.	P.m.	A.m.	P.m.	A.m.	P.m.
		Meters	*Meters*	*°C.*	*°C.*	*Percent*	*Percent*
June	36	672	544	13.3	14.1	89	85
July	56	559	454	16.3	17.7	92	85
August	60	502	419	17.3	18.6	91	81
Total	152						
Average		563	461	16.0	17.2	91	83

TABLE 5.—*Average height, mean temperature, and relative humidity of the point of highest temperature during June, July, and August, 1929–33, inclusive. For all observations*

Month	Number		Average height		Temperature		Relative humidity	
	A.m.	P.m.	A.m.	P.m.	A.m.	P.m.	A.m.	P.m.
			Meters	*Meters*	*° C.*	*° C.*	*Pct.*	*Pct.*
June	72	45	1,449	1,236	20.9	21.2	26	28
July	96	61	1,297	1,289	25.0	25.2	31	32
August	103	64	1,181	1,094	24.8	25.1	34	34
Total	271	170						
Average			1,293	1,202	23.8	24.1	30	32

TABLE 6.—*Average height, mean temperature, and relative humidity of the point of highest temperature during June, July, and August, 1929–33, inclusive. For a.m. and p.m. observations made the same day*

Month	Number	Average height		Temperature		Relative humidity	
		A.m.	P.m.	A.m.	P.m.	A.m.	P.m.
		Meters	*Meters*	*° C.*	*° C.*	*Percent*	*Percent*
June	36	1,445	1,253	20.6	20.7	25	28
July	54	1,332	1,270	24.7	25.1	31	31
August	60	1,164	1,101	24.9	24.8	33	35
Total	150						
Average		1,292	1,192	23.8	24.0	30	32

LITERATURE CITED

(1) Byers, H. R. Summer Sea Fogs of the Central California Coast. University of California Publications in Geography. Berkeley, Calif., 1930.

(2) Anderson, J. B., Lieut. Observations from Airplanes of Cloud and Fog Conditions along the Southern California Coast. MONTHLY WEATHER REVIEW. 59: 264–270. 1931.

(3) Thomas, J. W. Aerological Work of the Naval Air Station at San Diego. Bull. 12 of the Scripps Institution of Oceanography. La Jolla, Calif., 1926.

(4) Blake, D. Temperature Inversions at San Diego, as Deduced from Aerographical Observations by Airplane. With Discussion. MONTHLY WEATHER REVIEW. 56: 221–224. 1928.

(5) Reed, T. R. The North American High-Level Anticyclone. MONTHLY WEATHER REVIEW. 61: 321–325. 1933.

(6) Varney, B. M. Fog Phenomena of the Piedmont Littoral West of Los Angeles. Bull. American Meteorological Soc. 14: 125–126. May 1933.

(7) Bowie, E. H. The Summer Nighttime Clouds of the Santa Clara Valley, Calif. MONTHLY WEATHER REVIEW. 61: 40–41. 1933.

(8) Lange, K. O. Measurements of Vertical Air Currents in the Atmosphere. Technical Memorandums Nat. Advisory Comm. for Aeronautics, No. 648. Washington, November 1931.

(9) Willett, H. C. Fog and Haze: Their Causes, Distribution, and Forecasting. MONTHLY WEATHER REVIEW. 56: 435–468. 1928.

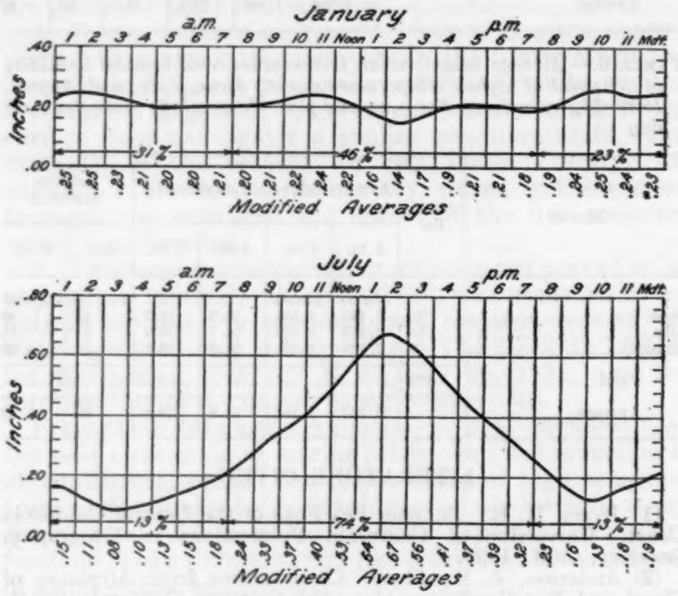
(10) Blake, D. Remarkably Low Humidities Aloft Over San Diego, Calif. MONTHLY WEATHER REVIEW. 61: 170. 1933.

HOURLY DISTRIBUTION OF RAINFALL AT MOBILE, ALA.

By HARRY ARMSTRONG

[Weather Bureau Office, Mobile, Ala., June 28, 1934]

The rainfall data for this article cover a period of 20 years, 1913–32, inclusive. Hourly averages were prepared for each month. In some cases there were marked differences for adjacent hours, but these were traced to unusually heavy thundershowers or the passage of tropical disturbances. The averages were smoothed by adding to double the value of the hour in question that of both the previous and the succeeding hour and dividing the sum by four. From these modified hourly averages, seasonal and yearly averages were prepared, and monthly, seasonal, and yearly graphs drawn, of which figure 1 is for January and July, respectively.



Modified hourly precipitation averages (hundredths of inches) for the 20-year period, 1913–32.

In May, June, July, August, and September the probability of rain is greatest between 1 and 3 p.m. for any day. During May and September the probability of rain at 2 p.m. is two and a half times greater than at midnight. In June the likelihood of rain is three times as great at 2 p.m. as for a like period at night; during July, five times as great; and during August, eight times as great.

Through the summer months, June, July, and August, Mobile has about five times the chance of getting rain in mid-afternoon, mostly in the form of local thunderstorms, as for a like period at night. The peak of precipitation is between 2 and 3 p.m. The average time of greatest rainfall occurs, as theory indicates it should, after that (around 1 p.m.) of the maximum temperature for the day. The average number of thunderstorms for the summer is 38, which is about 60 percent of the yearly average. During summer about 72 percent of the rain occurs between 7 a.m. and 7 p.m., as compared with 58 percent for the year. Also, about 50 percent falls during the 6 hours from 11 a.m. to 5 p.m. Fair weather at night and showers during the day seems to be a good forecast, for this period, when rain is probable.

In January, February, and November the rain is heaviest during the 12 hours, 7 p.m. to 7 a.m., about 55 percent occurring in this period. For the other 9 months the precipitation is heaviest from 7 a.m. to 7 p.m., about 60 percent being the average predominance. During January rain is fairly well distributed through the 24 hours with a slight increase at night. February has its heaviest rain at about 2 a.m. and its lightest at 7 p.m., though the difference is only slight. March shows a tendency to rain at 7 a.m. and to slacken up at midnight. April shows only a small variation. During October the period of rain is from 5 a.m. to 1 p.m. November has the biggest percent of rain at night of any month. Its bulge in the rain curve is at midnight. For December the wettest time is about mid-morning and the driest about 9 p.m. For the whole year the greatest rain period is at 2 p.m. The 9-month period, September to May, inclusive, has the highest precipitation at 7 a.m. and the lowest at 7 p.m., though the difference is small. The hourly distribution of rainfall for these 9 months is fairly uniform, with the total amount about equally divided between day and night.

LIGHTNING BRANCHES ON THE GROUND

By R. H. WEIGHTMAN

[Weather Bureau, Washington, D.C., July 1934]

On June 6, about 5 p.m., in the northwestern suburbs of Washington, D.C., about 6 miles from that city, a thunderstorm occurred in the warm sector of a depression with center over the Gulf of St. Lawrence. At that time a cold front was advancing southward over Pennsylvania, extending from the Maine coast west-southwestward to southern Ohio.

There were a number of lightning discharges in connection with this storm and it is desired to invite attention to one in particular that struck on the edge of the eighteenth putting green at the Kenwood Golf and Country Club, located on River Road. The course is undulating with trees bordering many of the fairways. The eighteenth green, which is roughly 90 feet in diameter, rises from the fairway as you approach the green to an elevation of about 7 feet at the back, with a rather sharp down slope at the rear to the general level of the surrounding terrain. The discharge, preceding and during which it was raining moderately, struck on this down slope at *B*, figure 1, about 2 feet below the putting surface. From that point two branches, *BK* and *BL*, extended down slope with an angle of about 75° between them. A third branch, *BEJ*, pursued a course up the slope as indicated in the diagram. A fourth branch, *IGH*, was distinctly traceable on the green but not connected along the surface at least with the main discharge at *B*. Soil was scattered about at the back of the green, on the down slope below *B* and even beyond *K* and *L* on the level terrain as much as 20 or 25 feet from *B*. The most disturbed condition of the ground was at *C*, where the earth had been exploded out to a depth of 8 or 10 inches, leaving a kind of funnel about 10 inches along the track

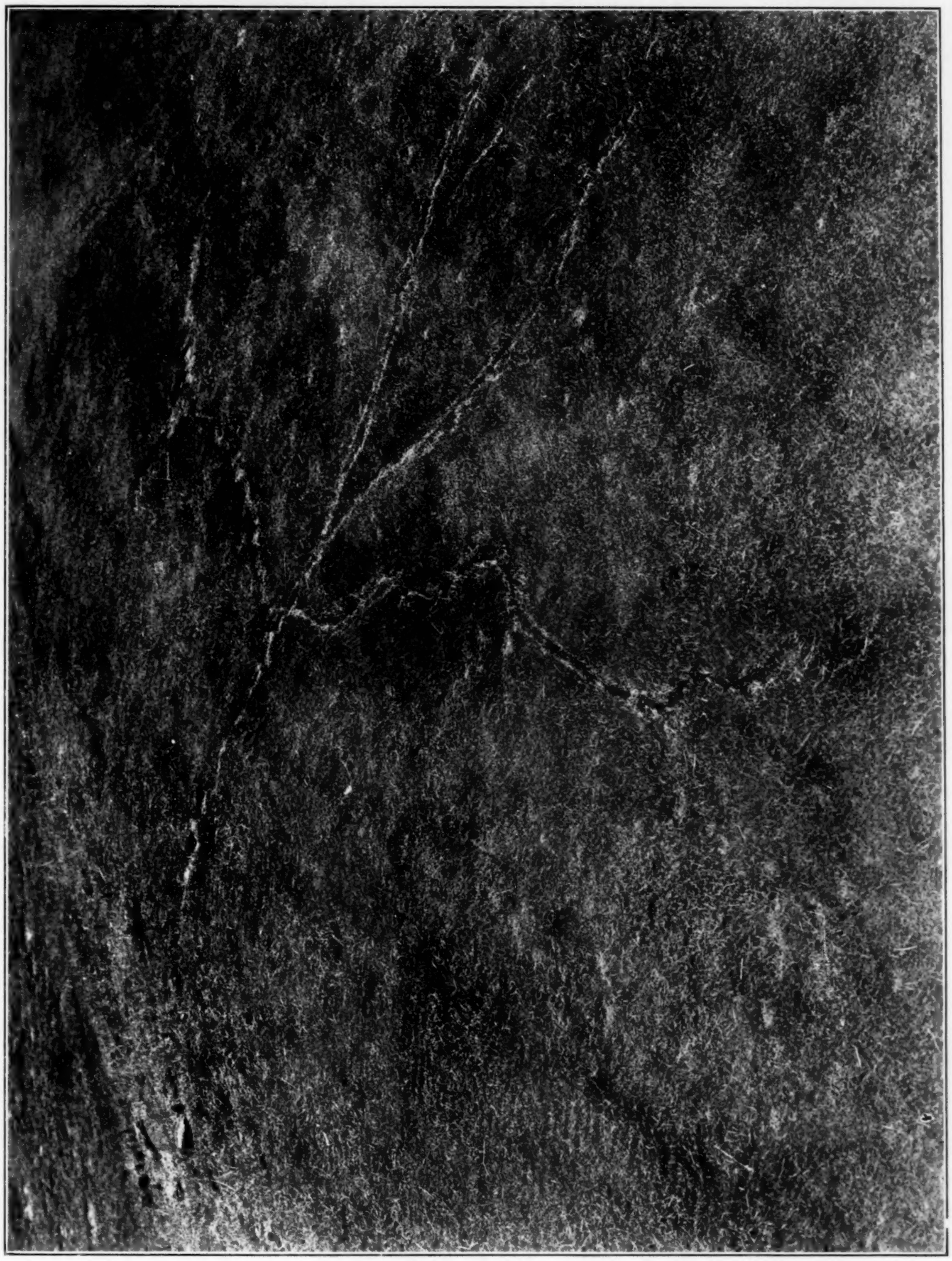


FIGURE 2.—Lightning path on putting green.

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and about 6 inches wide at the surface, tapering off to nothing at the bottom. The main discharge apparently was at *B*, as all connected branches radiate from that point. A^1, A^2, and A^3 are gaps in the branches where the turf is not disturbed in any way. Apparently at these places the discharge passed underneath the surface to resume its course again on the surface later on. There was no connection at the surface between *B* and *I*. Careful probings at *I* with a 6-foot collapsible carpenter's rule, which is in 6-inch sections, failed to reveal any hole.

By probing at *B* a hole was found, almost perpendicular, 43 inches in depth, but slanting a little with descent to the east-northeast, which must have been nearly straight throughout its course, otherwise the rule having flexibility in only one direction and a width of five-eighths inch in the other direction, could not have followed it. With the facilities at hand it could not be determined how much deeper, if any, this hole extended.

At *C* a hole was found 31 inches long, directed down slope toward *K*, 6 inches to 8 inches below the surface and nearly parallel to it. At *D* a hole was discovered extending 22 inches in the general direction of *B* but nearly horizontal.

The sod at *F* was severed in a clean-cut line for about 2 feet. The turf was carefully laid back by hand on each side of the line exposing a cavity about 1½-inches deep and 2 inches across. At *J* the terminus of a branch, there was a spot about three-eighths inch in diameter but prodding with the rule failed to indicate any depth to it. The branches *GHI*, and all ramifications on the green had no depth, the only evidence of the discharge being the searing of the grass which was changed to a yellowish brown color down to the roots, the path having a width decreasing from about three-eighths inch in the early part of its course to three-sixteenths of an inch at the ends. In the cavities at *C* and *F*, the grass roots were whitish, nearly their natural color, but were not scorched or blackened at all. Examination at *B* and other places where the sod was broken failed to reveal any fusing or discoloration of the soil.

The cloud layer from which the lightning discharge took place moved from the *WSW* to *ENE* and the hole at *B*, made by the discharge, had a slight inclination to the *ENE*.

The nearest trees to the eighteenth green are roughly 60 feet in height and distant about 150 feet. It seems somewhat strange that the discharge missed these inviting trees. It is perhaps more remarkable, however, that the flag marking the eighteenth hole, on a pole about 10 feet long, which was distant about 25 feet from the point where the lightning struck, should have escaped.

Many bolts of lightning strike the ground but relatively few accounts have been published regarding them. One case occurred at the Agricultural Experiment Station at College Park, Md., an account of which is published in

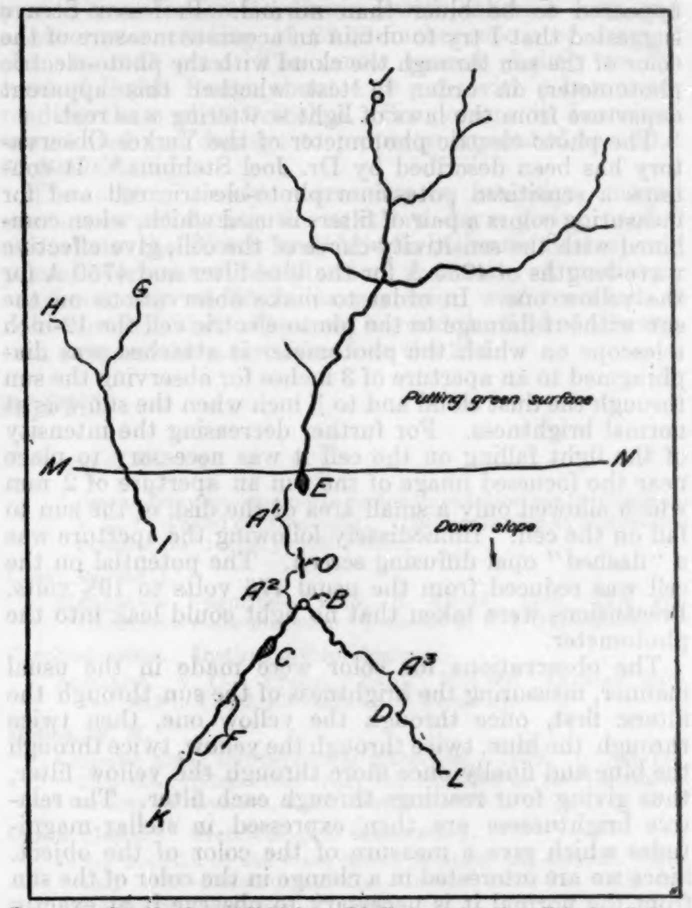

FIGURE 1.—Ramifications of lightning. *B* indicates point where lightning discharge struck the earth. *MN* delimits putting green surface.

the MONTHLY WEATHER REVIEW, volume 48, page 452, 1920.

Perhaps some of the most interesting cases are where the lightning strikes in sand and by its intense heat forms irregular glass tubes commonly known as "fulgurites" and which may have a diameter up to 2 inches or slightly more.

SOME OBSERVATIONS OF THE SUN THROUGH A DUST STORM

By C. T. ELVEY

[Yerkes Observatory, Williams Bay, Wis., June 1934]

The dust storm of May 10, 1934, presented an opportunity to the astronomer to make a comparison of a terrestial phenomenon with certain astronomical observations. An observer of the Milky Way sees that it is not uniform but cut in many places by dark patches. On photographs these dark areas and many others of smaller dimensions are evident, and a careful study of them shows that they are caused by the presence of cosmic dust clouds which cut out a part of the light of the stars which are behind them. A study of the character of the light that has traversed a cloud of dust gives some information concerning the particles composing the cloud. Particles which are less in diameter than the wave-length of the incident light scatter the light according to Rayleigh's law, that is in proportion inversely to the fourth power of the wave length, and consequently the transmitted light is redder than the incident light. If the particles are large in comparison with the wave-length of light, the scattering is independent of the wave-length and thus the color of the transmitted light is the same as that of the incident light. If the particles are of intermediate sizes the scattering is inversely proportional to the first, second, and third powers of the wave-length, but, as E. Schönberg [1] has shown, the range in size of such particles is small. Thus for a uniform mixture these intermediate powers may be neglected. Observations of the colors of the stars have shown some to be excessively reddened in

[1] Mitt. d. Sternwarte Breslau, *3*, 53, 1932.

comparison with the total obstruction of light while others show large diminution of light with only a slight amount of reddening.

When the dust storm of May 10 covered a large section of the Middle West one could see the sun shining faintly through the dust cloud and to the eye the color of the sun appeared to be bluer than normal. Professor Struve suggested that I try to obtain an accurate measure of the color of the sun through the cloud with the photo-electric photometer, in order to test whether this apparent departure from the laws of light scattering was real.

The photo-electric photometer of the Yerkes Observatory has been described by Dr. Joel Stebbins.[2] It contains a sensitized potassium photo-electric cell and for measuring colors a pair of filters is used which, when combined with the sensitivity-curve of the cell, give effective wave-lengths of 4250 A for the blue filter and 4750 A for the yellow one. In order to make observations on the sun without damage to the photo-electric cell the 12-inch telescope on which the photometer is attached was diaphragmed to an aperture of 3 inches for observing the sun through the dust cloud and to ¼ inch when the sun was at normal brightness. For further decreasing the intensity of the light falling on the cell it was necessary to place near the focussed image of the sun an aperture of 2 mm which allowed only a small area of the disk of the sun to fall on the cell. Immediately following the aperture was a "flashed" opal diffusing screen. The potential on the cell was reduced from the usual 176 volts to 19½ volts. Precautions were taken that no light could leak into the photometer.

The observations for color were made in the usual manner, measuring the brightness of the sun through the filters: first, once through the yellow one, then twice through the blue, twice through the yellow, twice through the blue and finally once more through the yellow filter, thus giving four readings through each filter. The relative brightnesses are then expressed in stellar magnitudes which give a measure of the color of the object. Since we are interested in a change in the color of the sun from the normal it is necessary to observe it at exactly the same altitude on a day when the sky is free from dust and clouds. This occurred 5 days later. In the meantime the photometer was left unchanged so as to introduce as few variables as possible into the comparison.

Two sets of observations were taken each on May 10 and on May 15, the date for comparison. The observed color of the sun through the dust cloud was $+0.83 \pm 0.03$ (average deviation) magnitudes. On May 15, when the transparency of the sky was judged as excellent for photometric purposes, the color of the sun was $+0.89 \pm 0.01$ magnitudes. The sense of the sign is such that larger positive numbers represent redder colors. Thus, it is seen that, if there is any change at all, it is in the direction of the sun being bluer as seen through the dust cloud. However, considering the difficulties involved and also considering the average deviations I would say that there had been no change in color. The difference is nearly equal to the sum of the average deviations. We can then conclude that there was an insufficient amount of dust fine enough to produce Rayleigh scattering even though the brightness of the sun was reduced to less than one percent[3] of its normal brightness. All of the dust particles must be larger than a few microns in diameter. This is perhaps what might have been expected since the dust was more or less of local origin, being picked up by the high winds over the drought stricken areas of the Great Plains. A sample of the dust falling here was collected by Dr. Keenan and an examination with a microscope showed that most of the particles averaged about 0.1 mm. in diameter.

The apparently decided blue color of the sun as seen visually through the dust cloud is merely an effect of contrast. One ordinarily sees the sun projected against a blue sky and of course the sun is yellower than the sky. The dust cloud had a brownish color and consequently the sun by contrast appeared bluer than normal.

[2] Astrophysical Journal, *74*, 289, 1931.

[3] This is determined from a comparison of the observations of the two days, taking into account the areas of the apertures admitting light to the telescope objective. The accurate comparison shows that the brightness of the sun as seen through the dust cloud at 9:43 a.m. C.S.T. on May 10 was 0.8 of 1 percent as bright as on May 15 at the same zenith distance.

THE TROPICAL DISTURBANCE OF JUNE 5–23

By G. E. Dunn

[Weather Bureau, Washington, Aug. 6, 1934]

The early history of this storm remains rather obscure. Disturbed conditions were noted in the Gulf of Honduras on the 4th and, as the depression had deepened and some movement was apparent, advices were issued the morning of the 5th, the day it crossed the coastline of British Honduras near Belize, where a maximum wind of 34 miles from the northwest was recorded. During that afternoon and night it apparently turned to the southwestward or south. On the morning of the 6th Tapachula, on the coast of Mexico, near the Guatemalan border, reported a barometer reading of 29.6 inches and a 24-hour fall of 0.18 inches. On June 7 the following message was received from the Pan American Airways station at San Salvador, Salvador:

> A severe storm struck this place early this morning with torrential rain and winds in excess of 50 miles per hour. Present wind south 30 miles per hour. Considerable damage reported due to heavy rain.

Press reports indicate that between 1,000 and 3,000 persons were killed or injured in Honduras, perhaps due to floods in the majority of cases. The town of Ocotepeque in western Honduras suffered greatly, with more than 500 people killed. Only the church remained standing after the flood. The rainfall, according to some reports, was in excess of 25 inches at a number of places. Great destruction and suffering occurred in both Salvador and Honduras.

Because of the extreme paucity of reports from this area considerable conjecture is necessary, but the disturbance may have moved southwestward or southward from British Honduras to the Guatemalan or Salvadorean coast, intensified along their Pacific coasts, and recurved inland again over Salvador, crossed Honduras and passed northward into the Gulf of Honduras where it was definitely located on the 8th. During its passage over this Gulf it apparently regained hurricane intensity once more and then passed inland over the extreme northern portion of British Honduras in the late afternoon of the 8th. On the 9th it crossed the Yucatan peninsula and moved into the Gulf of Mexico. The Mexican Meteorological Service reported that winds of hurricane force occurred over a portion of the peninsula.

During the next 2 days this disturbance continued to move northwestward, but on the 12th made a complete

loop in the southwestern Gulf of Mexico and then began to move slowly north-northeastward. On the afternoon of the 15th the first vessel report from the vicinity of the center was received, the S.S. *Belfast Maru*, about 240 miles south of the Louisiana coast, reporting a wind velocity of 70 miles from the south-southeast and a barometer reading of 28.76 inches. The following warning was immediately issued:

Hoist northeast storm warnings 4 p.m. Pensacola, Fla., to Morgan City, La. Tropical disturbance central 1 p.m. about 26° N. and 96° 40 minutes W. moving slowly north-northeastward attended by shifting gales and probably by winds of hurricane force near center. Caution advised vessels in path. Present indications are that center will reach eastern Louisiana coastline Saturday afternoon or night.

Hurricane warnings were ordered the next morning between Grand Isle and Vermilion Bay, La. As the storm approached the Louisiana coast, its rate of movement increased and Dr. I. M. Cline, of the Weather Bureau at New Orleans, reports that between Jeanerette and Baton Rouge, La., it traveled about 27 miles per hour—an unusually rapid rate. It crossed the coastline a short distance west of Morgan City, which reported a barometer reading of 28.9 inches and a wind velocity of 68 miles from the southeast at 2 p.m. The center passed over Jeanerette, Iberia Parish, where a calm and a barometer reading of 28.58 inches occurred from 2 p.m. to 2:45 p.m. The center passed slightly to the west of Baton Rouge about 4:10 p.m. with a barometer reading there of 28.8 inches. Six persons in Louisiana were killed and damage to property amounted to about $2,605,000.

The storm, slowly decreasing in intensity, moved northeastward during the next few days, giving needed rainfall to the North and Middle Atlantic States, and passed over central Maryland on the 19th. A maximum wind velocity of 50 miles per hour was recorded at Atlantic City, N.J. It passed beyond the field of observation over northern Greenland on the 23d.

BIBLIOGRAPHY

C. FITZHUGH TALMAN, *in charge of Library*

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Anderson, Abram E.

Sand fulgurites from Nebraska. Their structure and formative factors. 1925. p. 49–86. illus. 22½ cm. (Nebraska state museum. Bulletin 7, v. 1, June 1925.)

Barbour, Erwin Hinckley.

Notes on Nebraska fulgurites. 1925. p. 45–48. illus. 22½ cm. (Nebraska state museum. Bulletin 6, v. 1, June 1925.)

Bjerknes, Vilhelm Friman Koren, *& others*.

Hydrodynamique physique avec applications a la météorologie dynamique. Paris. Les Presses universitaires de France, 1934. 3 v. illus. (incl. charts), diagrs. 24½ cm. (Recueil des conferences—rapports de documentation sur la physique. v. 23.) Paged continuously. "Bibliographie et indications historiques": v. 3, p. [839]–850.

Cook, Harold J.

Manganese fulgurites. 1925. p. 41–44. illus. 22½ cm. (Nebraska state museum. Bulletin 5, v. 1, June 1925.)

Czechoslovakia. Institut météorologique.

Annuaire. v. 15. Praha. 1930. 30½ cm. [Author, title, and text in Czechoslovakian and French.]

Hobbs, W. H.

Climatic zones and periods of glaciation. 1929. p. 735–744. 25½ cm. (Reprinted from the Bulletin of the Geological society of America, v. 40, Dec. 31, 1929.)

Osaka (Japan). Meteorological observatory.

(The) bulletin of the observation of upper air current. January 1928–December 1931. Osaka. 1928–31. 26½ cm. [Japanese and English.]

SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING JUNE 1934

By IRVING F. HAND, *Assistant in Solar Radiation Investigations*

For a description of instruments employed and their exposures, the reader is referred to the January 1932 REVIEW, page 26.

Table 1 shows that solar radiation intensities averaged above normal for June at Madison and close to normal at Washington and Lincoln.

Beginning with this issue, summaries of the total radiation (direct + diffuse) received on a horizontal surface at the University of Washington Oceanographic Laboratory, Friday Harbor, Washigton (latitude 48° 32′ N., longitude 123° 01′ W.; height above sea level 4.37 meters), will be regularly included in table 2 through the kind cooperation of Dr. C. L. Utterback. The radiation equipment at that station comprises an Eppley pyrheliometer (no. 262) recording on an Engelhard microammeter (no. 30737). Table 2–A gives the radiation values from this station for the International Polar Year, July 30, 1932, to August 19, 1933, inclusive.

Table 2 shows an excess in the total solar radiation received on a horizontal surface at all stations with the exception of Pittsburgh and Miami.

Beginning with this month, *air mass* types will be indicated with screened radiation measurements, as shown in the last column of table 3.

Polarization measurements made on 4 days at Washington give a mean of 56 percent with a maximum of 57 percent on the 28th. At Madison, measurements made on 7 days give a mean of 65 percent with a maximum of 70 percent on the 21st. The values for Washington are slightly below normal for June, while those at Madison are above normal.

TABLE 1.—*Solar radiation intensities during June 1934*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D.C.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	A.M.					P.M.				Local mean solar time
	e	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e
	mm	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm
June 13	9.47				1.00	1.37					8.81
June 14	10.21				1.11	1.39					9.47
June 15	12.68			0.70	.94	1.33					11.35
June 21	17.37					1.28					18.59
June 25	17.37				.98	1.33					15.11
June 28	17.96			.43	.63	1.12					19.23
June 29	21.28				.88	1.20					19.89
Means				.56	.92	1.30					
Departures				−.21	−.02	+.06					

MADISON, WIS.

Date	e	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e
June 1	11.38					1.30					12.68
June 8	8.81					1.22					15.11
June 9	13.61					1.34					17.37
June 11	9.83			1.10	1.24	1.37					9.83
June 12	8.18		0.94	1.07	1.25	1.46					8.81
June 13	9.83		.92	1.05	1.22	1.46					9.14
June 16	7.87				1.14	1.43					7.57
June 18	13.13				1.24	1.53					9.83
June 19	9.83		.84	1.00	1.18	1.39					10.59
June 20	14.60					1.21					16.20
June 21	11.81		.94	1.10	1.27	1.46					10.97
June 23	16.79		.82	.91	1.14	1.41					15.65
June 26	16.20					1.31					18.59
June 28	13.61					1.32					16.20
Means			.89	1.04	1.21	1.37					
Departures			+.04	+.08	+.19	+.05					

LINCOLN, NEBR.

Date	e	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e
June 5	16.79			0.97	1.14	1.41					11.35
June 7	15.11		0.78	.92	1.09	1.39					14.60
June 9	12.68						1.01	0.84	0.68		10.97
June 11	12.24					1.21	1.03	.88	.75		10.59
June 13	8.18		.73	.88	1.07	1.41					9.14
June 18	10.59					1.42	1.25	1.08			7.57
June 20	13.13			.55	.80	1.24	1.03	.77	.65	0.54	12.24
June 21	10.21		.95	1.08	1.22	1.40	1.17	1.00	.88	.76	7.87
June 22	14.60					1.36	1.21	1.02	.83	.70	15.11
June 23	18.59		.75	.90	1.10						17.37
June 24	16.20					1.30					13.13
June 25	14.60						1.09	.91	.70		13.13
June 26	13.61	0.66	.77	.90	1.10	1.34					11.38
June 27	11.38					1.34	1.11	.90	.76		9.83
June 28	12.24		.83	.98	1.17	1.36	1.08				10.59
Means		0.66	.80	.91	1.09	1.35	1.11	.92	.75	.67	
Departures			+.03	−.02	−.01	+.00	+.01	+.01	−.03	+.02	

[1] Extrapolated.

TABLE 1.—*Solar radiation intensities during June 1934*—Continued

BLUE HILL, MASS.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	A.M.					P.M.				Local mean solar time
	e	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e
	mm	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm
June 2	14.6				0.91	1.21					11.4
June 6	16.2					1.26					13.8
June 7	9.1					1.30	1.12	0.99			8.0
June 8	5.0					1.39	1.12	1.03	0.95		4.0
June 10	14.0				.96	1.29					9.0
June 11	14.6					1.34	1.03				11.5
June 12	10.2					1.20					10.0
June 14	10.2					1.29					10.5
June 15	9.8				1.19	1.38					8.5
June 16	13.1				.98	1.21					11.2
June 17	11.0				1.09	1.36	1.14	.87			8.0
June 18	9.1			1.00	1.19	1.41	1.14				7.7
June 20	9.1				1.22	1.44	1.05				7.8
June 22	10.2				1.22	1.45	1.06				9.1
June 23	11.0					1.19	1.03	.85			11.7
June 24	14.6					1.25					12.2
June 25	7.6				1.14	1.35	1.13	1.01			6.8
June 26	7.0					1.43					8.2
June 29	9.8					1.04					12.7
June 30	13.0					1.26	1.12				13.8
Means				1.00	1.10	1.30	1.09	.95	.95		

LATE REPORT (BLUE HILL, MASS.)

Date	e	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e
May 1	5.8				1.15	1.45					4.6
May 5	12.7				1.03	1.20					7.0
May 6	4.6				1.33	1.47					5.2
May 8	5.4				1.19	1.48	1.25				2.5
May 9	3.3				1.19	1.35					4.2
May 12	4.8				1.04	1.31					3.9
May 13	4.0				1.11	1.40					2.8
May 16	3.9					1.48	1.15	0.88			1.9
May 18	6.0				.73	1.39					5.6
May 19	4.0				1.12	1.42					2.9
May 22	11.4				1.00	1.27					9.5
May 23	7.3					1.46	1.09				3.3
May 24	5.4				1.03	1.49	1.03	.79			5.0
May 27	6.5				.99	1.37					5.6
May 30	13.6					1.18					9.9
May 31	13.6				.77	1.21					10.5
Means					1.05	1.37	1.13	.84			

TABLE 2.—*Average daily totals of solar radiation (direct+diffuse) received on a horizontal surface*

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Fresno	Pittsburgh	Fairbanks	Twin Falls	La Jolla	Miami	New Orleans	Riverside	Blue Hill	Mount Washington	Friday Harbor
	Gram calories per square centimeter															
1934	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
June 4	479	549	597	515	466	587	479	492	556	508	409	446	485	559		671
June 11	551	488	576	526	573	745	460	538	666	462	427	460	523	588		685
June 18	551	630	667	537	522	748	470	543	640	475	526	520	598	570		689
June 19	595	593	595	452	560	734	483	515	683	562	462	484	577	601		622
	Departures from weekly normals															
June 4	−18	+35	+46	+78	+39	−97	+2	+44	−37	+72	−93	−34				
June 11	+55	−16	+35	+95	+137	+57	−24	+48	+26	+70	−69	+10				
June 18	+57	+102	+97	+76	+87	+38	−20	+21	−40	+17	+12	+102				
June 25	+66	+55	−5	+20	+113	+28	+5	+28	+44	−4	−88	+71				
	Accumulated departures on July 1															
	+553	+3,122	+5,999	+6,671	+9,863	+4,396	−1,918	+581	+3,171	+10,248	−2,842	+5,509				

NOTE.—The pyrheliometer in use at Mount Washington was damaged by lightning. Plans are now being made for its replacement.

TABLE 2-A.—*Average daily totals of solar radiation (direct+diffuse) received on a horizontal surface at Friday Harbor, Wash.*

Week beginning—	Gram calories per cm²	Week beginning—	Gram calories per cm²	Week beginning—	Gram calories per cm²
1932	*cal.*	1932	*cal.*	1933	*cal.*
July 30	[1] 633	Dec. 3	91	Apr. 23	516
Aug. 6	438	Dec. 10	111	Apr. 30	411
Aug. 13	506	Dec. 17	68	May 7	589
Aug. 20	[1] 565	Dec. 24 [2]	[1] 73	May 14	437
Aug. 27	460			May 21	472
Sept. 3	444	1933		May 28	589
Sept. 10	411	Jan. 1	37	June 4	701
Sept. 17	347	Jan. 8	71	June 11	680
Sept. 24	373	Jan. 15	111	June 18	548
Oct. 1	338	Jan. 22	76	June 25	448
Oct. 8	140	Jan. 29	152	July 2	644
Oct. 15	136	Feb. 5	176	July 9	615
Oct. 22	169	Feb. 12	126	July 16	625
Oct. 29	108	Feb. 19	204	July 23	667
Nov. 5	106	Instrument defective during this interim		July 30	489
Nov. 12	85			Aug. 6	588
Nov. 19	103			Aug. 13	571
Nov. 26	40				

[1] Incomplete record.
[2] 8-day mean.

TABLE 3.—*Total, I_m and screened, I_y, I_r, solar radiation intensity measurements, obtained during June 1934, and determinations of the atmospheric turbidity factor, β, and water-vapor content, w=depth in millimeters, if precipitated*

AMERICAN UNIVERSITY, WASHINGTON, D.C.

Date and hour angle	Solar altitude	Air mass	I_m	I_y	I_r	$\beta_{I_{m-r}}$	$\beta_{I_{y-r}}$	β_{mean}	$\frac{I_{w-o}}{1.94}$ (Percentage of solar constant)	$\frac{I_{w-o}-I_m}{1.94}$[1] (Percentage of solar constant)	w	Air mass type
June 13	° ′	*m*	*Gr. cal.*	*Gr. cal.*	*Gr. cal.*						*mm*	
3:18a	45 22	1.40	1.170	0.815	0.630	0.072	0.067	0.070	75.8	14.7	50	P_p.
3:14a	46 08	1.39	1.204	.816	.630	.056	.068	.062	78.5	15.7	60	
1:01a	69 38	1.06	1.341	.880	.678	.036	.052	.044	84.6	14.6	65	
0:57a	70 08	1.06	1.272	.880	.678	.078	.052	.065	82.2	15.8	80	
June 14												
3:59a	37 27	1.64	1.200	.838	.712	.056	.155	.106	67.6	4.9	2	P_p.
3:56a	38 02	1.62	1.153	.838	.712	.076	.148	.112	66.8	6.6	3	

Atmospheric conditions. June 13, temp. 25° C., wind, 15–NW. Cu.p.m.; June 14, temp. 27° C. wind, 14–NW. Cu.p.m.

BLUE HILL METEOROLOGICAL OBSERVATORY OF HARVARD UNIVERSITY

Date and hour angle	Solar altitude	Air mass	I_m	I_y	I_r	βI_{m-r}	βI_{y-r}	β mean	$\frac{I_{w-o}}{1.94}$ (Percent of solar constant)	$\frac{I_{w-o}-I_m}{1.94}$[1] (Percent of solar constant)	w	Air mass type
1934 June 2	° ′	*m*	*Gr. cal.*	*Gr. cal.*	*Gr. cal.*						*mm*	
3:23 a.	43 26	1.45	1.066	0.756	0.594	0.100	0.100	0.100	71.7	15.2	60.0	N_{PC}.
2:28 a.	53 17	1.25	1.125	.788	.616	.112	.100	.106	72.2	17.7	60.+	N_{PC}–T_A.
2:12 p.	56 39	1.19	.976	.727	.551	-----	.098	.098	75.7	13.9	48.0	
June 6												
2:04 a.	57 29	1.09	1.261	.850	.661	.057	.050	.054	81.7	14.7	50.0	.T_A, T_A aloft.
0:23 a.	70 02	1.06	1.261	.845	.647	.062	.060	.061	82.8	15.8	60.+	
June 7												
4:04 p.	36 14	1.69	1.179	.849	.678	.076	.068	.072	72.9	10.3	9.7	P_C.
4:29 p.	31 37	1.90	1.133	.794	.644	.063	-----	.063	73.5	13.3	29.5	
5:10 p.	24 08	2.44	1.101	.780	.623	.039	0.56	.048	70.6	12.2	11.6	
June 8												
1:57 p.	67 17	1.09	1.357	.911	.734	.058	-----	.058	82.4	10.3	13.2	P_C.
3:36 p.	41 28	1.51	1.202	.841	.663	.076	.067	.072	75.0	11.1	15.0	
4:30 p.	31 39	1.90	1.088	.764	.613	.069	-----	.069	71.3	13.5	31.0	
June 10												
0:25 a.	70 06	1.06	1.270	.873	.695	.089	.112	.100	78.6	11.1	24.0	T_G.

TABLE 3.—*Total, I_m and screened, I_y, I_r, solar radiation intensity measurements, obtained during June 1934, and determinations of the atmospheric turbidity factor, β, and water-vapor content, w=depth in millimeters, if precipitated*—Continued

BLUE HILL METEOROLOGICAL OBSERVATORY OF HARVARD UNIVERSITY—Continued

Date and hour angle	Solar altitude	Air mass	I_m	I_y	I_r	βI_{m-r}	βI_{y-r}	β mean	$\frac{I_{w-o}}{1.94}$ (Percent of solar constant)	$\frac{I_{w-o}-I_m}{1.94}$[1] (Percent of solar constant)	w	Air mass type
1934 June 11	° ′	*m*	*Gr. cal.*	*Gr. cal.*	*Gr. cal.*						*mm*	
1:28 a.	63 33	1.11	1.235	0.840	0.686	0.109	0.179	0.144	71.7	6.1	2.7	P_A, T_A aloft.
2:00 p.	58 36	1.17	1.315	.907	.708	.058	.050	.054	81.9	12.0	29.0	N_{PC}, T_A
3:28 p.	43 05	1.46	1.228	.849	.667	.056	.063	.060	77.6	12.3	25.0	
4:25 p.	32 35	1.86	1.072	.773	.612	.081	.078	.080	69.7	12.7	24.0	
June 12												
1:01 a.	67 07	1.09	1.067	.765	.605	.175	.160	.168	69.4	12.7	40.0	P_A, T_A aloft.
June 14												
3:16 a.	45 28	1.40	1.148	.831	.661	.115	.096	.106	71.8	10.7	14.0	N_{PC}.
June 15												
1:47 a.	61 08	1.14	1.372	.932	.739	.048	.064	.056	81.7	8.7	7.3	N_{PC}.
0:15 a.	70 51	1.06	1.391	.955	.744	.047	.031	.039	85.6	11.6	30.0	
June 16												
3:53 a.	38 38	1.60	.983	.729	.595	.159	.143	.151	62.3	10.0	9.0	P_C.
3:22 a.	45 00	1.41	1.029	.755	.619	.173	.175	.174	63.4	8.7	5.7	
0:43 a.	69 08	1.07	1.167	.840	.665	.153	.124	.138	73.0	10.9	22.0	
0:12 a.	70 59	1.06	1.173	.841	.663	.149	.112	.130	74.3	11.9	33.0	
0:38 p.	69 34	1.06	1.200	.830	.658	.118	.130	.124	75.1	11.2	26.0	N_{PC}.
2:10 p.	57 08	1.19	1.133	.80	.638	.134	.114	.124	72.7	12.4	33.0	
June 17												
3:59 a.	37 32	1.64	1.182	.850	.6	.087	.098	.092	70.3	7.4	3.2	N_{PC}.
0:45 a.	70 00	1.06	1.308	-----	.710	.082	-----	.082	79.8	10.2	17.0	
0:52 p.	68 18	1.08	1.330	.924	.714	.064	.031	.048	83.1	12.3	36.0	N_{PC}.
4:06 p.	36 14	1.69	1.200	.843	.665	.054	.056	.055	77.1	13.2	30.0	
5:11 p.	24 16	2.42	1.058	.767	.607	.050	.050	.050	70.1	13.8	29.0	
June 18												
5:12 a.	24 05	2.44	1.104	.796	.646	.049	.065	.057	68.5	9.7	6.0	N_{PC}.
3:26 a.	43 37	1.45	1.304	.920	.732	.057	.051	.054	79.7	10.7	11.5	
2:58 a.	48 41	1.33	1.347	.936	.750	.053	.067	.060	79.3	7.6	3.1	
1:00 a.	67 26	1.09	1.392	.967	.750	.048	.013	.030	86.5	12.1	33.0	
3:25 p.	43 48	1.44	1.360	.937	.742	.031	.041	.036	82.0	9.7	9.0	N_{PC}.
3:58 p.	37 43	1.63	1.295	.914	.696	.027	-----	.027	83.2	14.4	45.0	
June 20												
3:27 a.	43 28	1.45	1.325	.920	.731	.043	.051	.047	80.0	9.6	7.1	N_{PP}.
2:28 a.	54 06	1.24	1.380	.943	.736	.027	.027	.027	85.5	12.0	27.0	
0:17 a.	70 55	1.05	1.347	.926	.725	.065	.054	.060	83.8	12.1	35.0	
0:50 p.	68 33	1.07	1.342	.881	.692	.045	.059	.052	83.4	12.0	33.0	P_C.
3:28 p.	43 17	1.46	1.239	.854	.668	.051	.056	.054	78.7	12.7	29.0	
June 22												
4:06 a.	36 16	1.69	1.034	.928	.733	.039	.031	.035	80.0	10.6	11.2	P_C.
3:28 a.	43 17	1.46	1.378	.960	.747	.025	.009	.017	85.2	11.8	20.0	
2:04 a.	58 11	1.18	1.434	.965	.759	.028	.037	.032	85.5	9.3	9.0	
1:45 a.	61 13	1.14	1.429	.971	.752	.032	.023	.028	85.7	9.6	11.0	
1:31 a.	63 24	1.12	1.424	.981	.759	.031	.002	.016	88.2	12.4	35.0	
1:00 p.	67 28	1.09	1.373	.942	.728	.043	.019	.031	86.2	13.1	43.6	N_{PC}.
3:28 p.	43 17	1.46	1.295	.896	.682	.029	.002	.016	85.4	16.4	60.+	
June 23												
4:23 p.	32 00	1.88	1.054	.763	.622	.096	.106	.101	66.0	9.6	7.1	N_P.
June 24												
3:29 a.	43 05	1.46	1.163	.809	.643	.081	.093	.087	73.4	11.1	14.0	N_{PC}, T_P & T_C aloft.
3:08 a.	46 56	1.37	1.168	.809	.643	.076	.102	.089	74.4	11.9	24.0	
2:38 a.	52 19	1.26	1.172	.820	.639	.060	.079	.070	78.6	15.9	60.+	
1:38 a.	69 28	1.07	1.235	.854	.665	.092	.081	.086	79.2	13.1	44.0	
June 25												
3:29 a.	43 04	1.46	1.259	.854	.672	.050	.063	.056	78.2	10.8	14.0	P_C.
3:07 a.	47 06	1.37	1.264	.857	.676	.048	.071	.060	78.6	10.9	16.0	
2:43 a.	51 25	1.28	1.295	.876	.678	.040	.044	.042	82.8	13.5	42.0	
1:19 a.	65 01	1.10	1.318	.882	.687	.048	.065	.056	82.6	12.0	32.0	
0:52 a.	68 18	1.08	1.332	.896	.698	.049	.058	.054	83.1	11.8	31.0	
2:54 p.	49 27	1.31	1.267	.840	.666	.045	.075	.060	79.5	11.7	23.0	P_C.
4:16 p.	34 25	1.77	1.171	.843	.696	.086	.103	.094	68.6	6.4	2.4	

[1] Reduced to mean solar distance.

TABLE 3.—*Total, I_m and screened, I_y, I_r, solar radiation intensity measurements, obtained during June 1934, and determinations of the atmospheric turbidity factor, β, and water-vapor content, w=depth in millimeters, if precipitated*—Continued

BLUE HILL METEOROLOGICAL OBSERVATORY OF HARVARD UNIVERSITY—Continued

Date and hour angle	Solar altitude	Air mass	I_m	I_y	I_r	βI_{m-y}	βI_{y-r}	βmean	$\frac{I_{y-o}}{1.94}$ Percent of solar constant	$\frac{I_{y-o}-I_m^1}{1.94}$ Percent of solar constant	w	Air mass type
1934 *June 26*	′ °	m	Gr. cal.	Gr. cal.	Gr. cal.						mm	
2:17 a	55 57	1.20	1.395	0.944	0.749	0.040	0.058	0.049	82.4	8.1	4.8	P_C, T_G approaching aloft.
2:00 a	58 47	1.17	1.395	.961	.753	.040	.012	.026	86.2	11.9	28.5	
1:29 a	63 36	1.11	1.425	.958	.740	.026	.012	.019	87.9	12.0	32.0	
June 29												
2:28 a	54 00	1.24	1.002	.688	.550	.150	.190	.170	66.0	13.6	43.0	T_C.
2:06 a	58 22	1.18	.993	.688	.550	.167	.200	.184	65.8	12.9	38.0	
June 30												
3:18 a	44 57	1.41	1.291	.880	.681	.033	.050	.042	81.4	12.2	25.0	N_{PC}, T_G aloft.
2:49 p	50 53	1.28	1.220	.836	.654	.071	.075	.073	77.8	12.5	30.0	
3:57 p	37 46	1.63	1.078	.758	.586	.077	.070	.074	73.3	14.2	42.5	

NOTE.—For the significance of the symbols in column headed "Air mass types, see Willett, H. C., American Air Mass Properties. Papers on Physical Oceanography and Meteorology. Published by the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution. Vol. 2, Cambridge, Mass., June 1933.

Atmospheric conditions during solar radiation measurements

BLUE HILL METEOROLOGICAL OBSERVATORY OF HARVARD UNIVERSITY

Date and time from apparent noon	Air temperature °C.	Wind (Beaufort scale)	Visibility	Sky blueness	Clouds and remarks
June 1934					
2, 3:23 a.m	24.4	SW 5	6-7	5	1 Ci, 1 Acu; gusty.
2, 2:28 a.m	25.6	SW 6	6-7	5	1 Ci; 1 Acu; gusty.
2, 2:12 p.m	28.9	SW 5		5	1 Ci; dense haze.
6, 2:04 a.m	25.6	WSW 5	7	6	2 Ci, few Frcu; haze.
6, 0:23 a.m	26.7	SW 6	7	6	1 Ci, 1 Cu; light haze, very gusty.
7, 4:04 p.m	17.8	NNW 1	8	6	1 Cu; light haze.
7, 5:10 p.m	18.3	NW 3	8-9	7	1 Ci, few Cu.
8, 1:57 p.m	19.4	W&N 1	8-9	6	3 Ci; very clear.
8, 3:36 p.m	20.0	SW&W 3		7	Few Cicu; sea breeze.
8, 4:30 p.m	17.8	SW 4		7	4 Cist.
10, 0:25 a.m	25.0	W 3	8	6	3 Ci, Cicu, few Cu; Cicu 10° from sun, apparently changing.
11, 1:28 a.m	21.7	W&N 3	8	6	2 Acu, 2 Cu 10° from sun.
11, 2:00 p.m	23.9	W&N 3	9	7	3 Cu, 1 Acu; gusty.
11, 3:28 p.m	23.9	W&N 2	8-9	7	1 Ci, 2 Cu.
12, 1:01 a.m	15.6	E&N 1			3 Cicu, few Cu; dense haze.
14, 4:00 a.m	15.6	NW 4		7	2 Acu; light haze, gusty.
14, 2:35 a.m	18.3	NW 1		7	1 Acu, 3 Cu, Stcu; thin Frcu over sun spoiled one reading.
15, 4:20 a.m	16.7	WNW 2	8		3 Ci, Cist, Cicu; Cist layer over sun before last reading completed.
15, 0:45 a.m	18.3	NW 2	8-9		1 Ci, 2 Acu, few Cu, 5 Frcu; thin Acu over sun during last cooling.
15, 1:30 p.m	16.7	WNW 5	7-8		Few Cist; Cu, Frcu near sun.
16, 3:33 a.m	18.9	NW 2	8	6	2 Acu, 1 Cu.
16, 0:50 a.m	17.2	NE 4			2 Cu, Frcu, Acu; sun clear; haze on all horizon.
16, 0:12 a.m	17.2	NE 4	7-8		
16, 2:10 p.m	16.1	NE 4	7-8		Few Cu, Frcu; 1 Acu 10° from sun.
17, 3:00 a.m	13.3	NW 1	7	7	4 Cu.
17, 0:45 a.m	18.3	NE 1	8	7	3 Cu.
17, 0:52 p.m	20.6	NE 1	9	8	Few Acu, 3 Cu; light haze.
17, 5:11 p.m	21.1	ESE 1	9	7	1 Ci, few Cu.
18, 5:12 a.m	16.1	W 2	9	8	Few Ci.
18, 2:58 a.m	18.9	WSW 1	9	8	Few Ci.
18, 1:00 a.m	23.9	S&W 1	9	8	Few Ci, 3 Cu.
18, 3:25 p.m	23.9	S&W 4	9	8	1 Ci, few Cu.
20, 3:37 a.m	16.1	NNW 5	10	8	6 Cu, Stcu.
20, 0:50 p.m	22.2	NW 6	9	7	5 Cu.
20, 3:28 p.m	23.3	NW 4	9		2 Cu.
22, 4:06 a.m	22.2	WNW 4	9		2 Ci, few Acu.
22, 3:28 a.m	21.7	WNW 4	8-9		Few Ci, Cist on horizon.
22, 2:04 a.m	21.1	WNW 4			2 Ci, Cist, Cicu.
22, 1:00 p.m	23.9	WSW 2	9		2 Ci, Cist near sun.
22, 3:28 p.m	25.0	WNW 3	9		Few Cu, 1 Ci.
23, 4:23 p.m	18.3	NE 0		6	1 Frcu; fumulus 4° from sun.

Atmospheric conditions during solar radiation measurements—Con.

BLUE HILL METEOROLOGICAL OBSERVATORY OF HARVARD UNIVERSITY—Continued

Date and time from apparent noon	Air temperature ° C.	Wind (Beaufort scale)	Visibility	Sky blueness	Clouds and remarks
June 1934					
24, 1:45 a.m	22.2	SW 3	7	7	5 Ci; dense haze.
25, 3:20 a.m	21.7	W 2	8	7	Few Ci; light haze.
25, 2:43 a.m	22.2	W 2	8		Light haze.
25, 1:00 a.m	23.3	WNW 3	8		Few Cu, increasing; light haze.
25, 2:54 p.m	24.4	WNW 4	8-9		5 Stcu, St, Frcu; light haze.
25, 4:16 p.m	24.4	WNW 4-5	9		5 Stcu, St, Frcu.
26, 2:17 a.m	22.2	NW 3	9	7	4 Ci, 2 Acu.
26, 1:29 a.m	22.8	NW 2	9	7	4 Ci, few Acu.
29, 2:28 a.m	27.8	SW 3	5	5	7 Ci; dense haze.
30, 2:49 a.m	28.9	W 1	8	8	5 Ci.
30, 2:49 p.m	29.4	WSW 2	8-9		1 Cu.
30, 3:57 p.m	28.9	WSW 2	8-9		3 Cu, 1 Ci, Cist approaching sun.

POSITIONS AND AREAS OF SUN-SPOTS

[Communicated by Capt. J. F. Hellweg, U.S. Navy, Superintendent U.S. Naval Observatory. Data furnished by the U.S. Naval Observatory in cooperation with Harvard and Mount Wilson Observatories. The difference in longitude is measured from the central meridian, positive west. The north latitude is positive. Areas are corrected for foreshortening and are expressed in millionths of the sun's visible hemisphere. The total area for each day includes spots and groups]

Date	Eastern standard time	Heliographic: Diff. in longitude	Heliographic: Longitude	Heliographic: Latitude	Area: Spot	Area: Group	Total area for each day	Observatory
1934	h. m.	°	°	°				
May 1	11 14	No spots						U.S. Naval.
May 2	11 3	Do.						Mount Wilson.
May 3	10 58	Do.						Do.
May 4	13 44	−19.5	86.9	−20.5		46	46	U.S. Naval.
May 5	11 11	−6.0	88.6	−20.5		62	62	Do.
May 6	13 15	+9.0	89.2	−21.0		225	225	Mount Wilson.
May 7	11 12	+23.0	91.1	−20.5		62	62	U.S. Naval.
May 8	11 12	−27.0	27.9	+7.0	15			Do.
		+36.0	90.9	−20.5		93	108	
May 9	11 25	+51.0	92.6	−20.5		93	93	Do.
May 10	11 25	+65.0	93.3	−20.0		77	77	Do.
May 11	11 30	+75.0	90.0	−20.0		89	89	Mount Wilson.
May 12	11 34	No spots						U.S. Naval.
May 13	13 12	−78.0	269.7	−30.0		463	463	Do.
May 14	11 9	−65.0	270.6	−30.5		556	556	Do.
May 15	9 0	−57.0	266.6	−30.0	146			Mount Wilson.
		−53.0	270.6	−33.0		458	604	
May 16	11 40	−38.0	270.9	−30.5		494	494	U.S. Naval.
May 17	11 10	−75.0	220.9	+29.0		123		Do.
		−25.0	270.9	−30.5		494	617	
May 18	11 8	−60.0	222.7	+28.0		154		Do.
		−12.0	270.7	−30.5		401	555	
May 19	11 7	−46.0	223.5	+28.0		185		Do.
		+1.0	270.5	−31.0		278	463	
May 20	12 1	−31.0	224.8	+28.0	154			Do.
		+14.0	269.8	−31.0		216	370	
May 21	10 59	−18.0	225.1	+28.0	154			Do.
		+26.0	269.1	−31.0		185	339	
May 22	11 13	−30.5	199.2	+12.5	15			Do.
		−5.5	224.2	+28.0	154			
		+39.0	268.7	−31.0		154	323	
May 23	11 23	+8.0	224.4	+28.0	123			Do.
		+53.0	269.4	−31.0		93	216	
May 24	11 25	+20.0	223.2	+28.0	93			Do.
		+65.0	268.2	−31.0		77	170	
May 26	12 18	+44.8	221.0	+28.0	1,070		1,070	Harvard.
May 27	11 15	+58.0	221.5	+26.0	194		194	Mount Wilson.
May 28	11 47	+70.0	220.0	+28.0	62		62	U.S.Naval.
May 29	12 0	No spots						Mount Wilson.
May 30	13 27	Do.						U.S. Naval.
May 31	10 35	Do.						Do.
Mean daily area for 30 days							242	
June 1	11 22	No spots						Do.
June 2	11 13	Do.						Do.
June 3	11 44	Do.						Do.
June 4	11 25	Do.						Do.
June 5	13 20	Do.						Do.
June 6	11 15	Do.						Do.
June 7	13 26	Do.						Do.
June 8		Do.						Harvard.
June 9		Do.						Do
June 10	10 18	Do.						U.S. Naval.
June 11	13 36	Do.						Do.
June 12	9 15	Do.						Mount Wilson.
June 13	11 15	Do.						U.S. Naval.
June 14	11 17	Do.						Do.
June 15	13 15	−71.0	200.0	+3.0		185	185	Do.
June 16	11 56	−58.0	200.5	+3.0		185		Do.
		−10.0	248.5	−30.0		39	224	

POSITIONS AND AREAS OF SUN-SPOTS—Continued

Date	Eastern standard time		Heliographic			Area		Total area for each day	Observatory
			Diff. in longitude	Longitude	Latitude	Spot	Group		
1934	h.	m.	°	°	°				
June 17	12	32	−43.0	201.9	+3.0		185		U.S. Naval.
			+4.5	249.4	−30.0		31	216	
June 18	11	10	−27.0	205.4	+3.0		209		Mount Wilson.
			+18.0	250.4	−29.0		9	218	
June 19	13	12	−15.0	203.1	+2.5		170	170	U.S. Naval.
June 20	11	6	−3.0	203.0	+2.5		170	170	Do.
June 21	11	14	+14.0	206.7	+2.5	123		123	Do.
June 22	13	30	+28.5	206.7	+2.5	100		100	Do.
June 23	12	4	+41.0	206.8	+2.5	93		93	Do.
June 24	12	6	+54.5	207.0	+2.5	69		69	Do.
June 25	13	15	+68.0	206.6	+2.5	46		46	Do.
June 26	11	10	+82.0	208.5	+2.5	46		46	Do.
June 27	11	8		No spots					Do.
June 28	13	18		Do.					Do.
June 29	11	15		Do.					Do.
June 30	11	11		Do.					Do.
Mean daily area for 30 days								55	

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR JUNE 1934

(Dependent alone on observations at Zurich and its station at Arosa)

[Data furnished through the courtesy of Prof. W. Brunner, Eidgenössische Sternwarte, Zurich, Switzerland]

June 1934	Relative numbers	June 1934	Relative numbers	June 1934	Relative numbers
1	0	11	0	21	16
2	0	12	0	22	10
3	0	13	0	23	10
4	0	14	d 0	24	8
5	0	15	11	25	8
6	0	16	27	26	8
7	0	17	30	27	0
8	0	18	26	28	0
9	7	19	25	29	0
10	0	20	b 14	30	0

Mean: 30 days=6.7.

b=Passage of a large group or spot through the central meridian.
d=Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

[Aerological Division, D. M. Little, in Charge]

By L. T. SAMUELS

Free-air temperatures during June averaged mostly above normal, the largest departures occurring at Omaha. In striking contrast to the large positive departures at this station, those at Pembina to the northward were close to normal, being slightly below in the lower levels and slightly above in the higher levels. At Pensacola and San Diego, representing the Gulf and lower Pacific coast regions, respectively, the free-air temperatures averaged below normal. Relative humidity departures were in general of opposite sign to those of temperature with the largest values occurring at Pensacola and San Diego.

In connection with the difference in temperature departures at Omaha and Pembina as mentioned above, it is interesting to note that the resultant wind directions for the month at Omaha contained an appreciably greater south component than normal between the 1,000- and 4,000-meter levels and that the resultant velocities were considerably above normal at the latter station. Marked southerly components as compared to normal occurred in the resultant winds at a number of southern stations.

TABLE 1.—*Free-air temperatures and relative humidities obtained by airplanes during June 1934*

TEMPERATURES (° C.)

Altitude (meters) m.s.l.	Cleveland, Ohio[1] (246 meters)		Dallas, Tex.[2] (146 meters)		Norfolk, Va.[3] (3 meters)		Omaha, Nebr.[4] (300 meters)		Pembina, N.Dak.[5] (243 meters)		Pensacola. Fla.[3] (2 meters)		San Diego, Calif.[3] (5 meters)		Washington, D.C.[3] (2 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	18.9		24.6	(6)	25.4	+2.2	19.8	(6)	11.9	(6)	25.6	+0.5	18.9	−0.7	21.2	−1.2
500	20.5		25.3	(6)	23.3	+1.7	21.7	(6)	13.9	(6)	22.6	−.6	14.6	−1.7	21.7	+1.3
1,000	19.8	+4.0	23.8	+3.5	21.1	+1.8	22.8	+4.8	13.2	−0.9	19.7	−.8	12.8	−4.1	20.1	+1.9
1,500	17.5	+4.5	20.5	+2.5			20.4	+5.0	11.0	−.7						
2,000	15.1	+4.6	17.5	+2.0	14.3	+1.0	17.2	+4.5	9.3	+.5	14.0	−.8	14.0	−2.5	15.9	+3.2
2,500	12.3	+4.5	14.7	+1.8			13.4	+3.7	6.7	+.7						
3,000	9.2	+4.1	12.0	+1.9	8.9	+1.0	9.5	+2.8	3.9	+.8	8.5	−.7	9.4	−1.6	10.3	+3.1
4,000	2.7	+2.9	5.1	+.7			2.2	+1.9	−2.0	+.1	3.6	−.1	3.2	−1.3	3.3	+2.4
5,000	−3.5	+2.6	−2.4	−.5			−4.9	+.8	−7.9	+.2	−1.7	+.4			−3.6	+2.3

RELATIVE HUMIDITY (PERCENT)

Altitude (meters) m.s.l.	Cleveland Mean	Cleveland Departure	Dallas Mean	Dallas Departure	Norfolk Mean	Norfolk Departure	Omaha Mean	Omaha Departure	Pembina Mean	Pembina Departure	Pensacola Mean	Pensacola Departure	San Diego Mean	San Diego Departure	Washington Mean	Washington Departure
Surface	76		74	(6)	75	+1	79	(6)	86	(6)	85	+5	70	+1	79	+11
500	65		69	(6)	68	+1	67	(6)	74	(6)	81	+7	80	+3	69	+6
1,000	57	−10	63	−6	64	+1	53	−11	66	+1	78	+10	76	+18	66	+6
1,500	56	−10	63	+4			50	−11	60	−2						
2,000	52	−10	58	+7	63	+3	47	−11	54	−6	77	+14	38	+13	65	+5
2,500	52	−5	48	+1			49	−7	53	−5						
3,000	49	−4	41	−2	49	−3	50	−4	56	+1	70	+17	29	+12	53	0
4,000	50	+4	40	+1			52	0	54	+6	64	+18	25	+10	53	+5
5,000	47	+7	39	−4			47	−5	49	0	56	+17			40	+5

Times of observations: Weather Bureau, 5 a.m.; Navy, 7 a.m.; E. S. T.

[1] Temperature departures based on normals determined by extrapolating latitudinally those of Royal Center, Ind., and Due West, S.C. Humidity departures based on normals of Royal Center, Ind.

[2] Temperature departures based on normals determined by interpolating latitudinally those of Groesbeck, Tex., and Broken Arrow, Okla. Humidity departures based on normals of Groesbeck, Tex.

[3] Naval air stations.

[4] Temperature and humidity departures based on normals of Drexel, Nebr.

[5] Temperature departures based on normals determined by extrapolating latitudinally those of Ellendale, N.Dak., and Drexel, Nebr. Humidity departures based on normals of Ellendale, N.Dak.

[6] Surface and 500-meter departures omitted because of difference in time of day between airplane observations and those of kites upon which the normals are based.

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (eastern standard time) during June, 1934*

[Wind from N=360°, E=90°, etc.]

Altitude (meters) m.s.l.	Albuquerque, N. Mex. (1,554 meters)		Atlanta, Ga. (309 meters)		Bismarck, N. Dak. (518 meters)		Brownsville, Tex. (7 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Chicago, Ill. (192 meters)		Cleveland, Ohio (245 meters)		Dallas, Tex. (154 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	339	1.6	268	1.1	351	1.3	135	1.4	199	1.9	298	2.2	214	0.4	192	1.3	153	2.7	263	0.7	211	0.5	140	2.6
500			249	2.9			153	7.5	224	3.5			237	2.5	218	3.0	200	9.3			222	5.1	150	5.2
1,000			254	3.9	315	2.1	157	7.7	290	4.5			275	5.4	266	5.6	196	9.2	270	1.9	217	4.0	159	4.8
1,500			261	2.9	294	3.2	160	5.8	295	6.8			269	6.7	284	6.6	187	6.6	293	3.7	224	2.9	163	4.2
2,000	358	1.6	270	1.3	278	5.0	153	4.7	291	10.3	287	2.1	265	7.2	290	7.9	189	5.2	290	4.8	206	2.6	155	3.8
2,500	295	2.8	298	1.4	282	7.6	136	3.6	298	10.9	256	3.0	275	8.0	296	8.5	175	4.2	271	5.3	189	1.9	160	3.1
3,000	259	3.4	314	1.7	277	8.6	90	3.1	301	10.9	241	5.3	276	7.6	295	7.6	160	2.8	251	6.6	182	1.8	171	2.7
4,000	223	6.8	289	2.3	273	10.8	56	4.1	306	13.2	247	7.1	282	8.4	286	7.6	84	2.4	250	9.0	185	2.2	190	0.7
5,000	230	9.3	294	1.6	268	12.2	32	3.1			241	9.7	282	10.4	292	7.9	56	3.5	262	11.5	177	0.4	99	1.2

Altitude (meters) m.s.l.	Los Angeles, Calif. 217 meters)		Medford, Oreg. (410 meters)		Memphis, Tenn. (83 meters)		New Orleans, La. (19 meters)		Oakland, Calif. (8 meters)		Oklahoma City, Okla. (402 meters)		Omaha, Nebr. (306 meters)		Phoenix, Ariz. (338 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D.C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	165	0.2	303	0.7	180	0.8	202	1.1	259	0.9	167	3.7	144	1.1	99	1.4	158	2.6	35	0.2	129	1.0	262	0.4
500	143	1.5	295	1.4	225	4.8	225	2.4	282	3.1	180	7.0	182	3.2	246	1.1			352	1.2	40	0.9	272	4.5
1,000	12	0.8	316	1.7	246	3.2	161	2.1	337	5.3	202	13.1	217	7.1	263	2.8			310	2.9	359	1.5	290	5.9
1,500	332	2.5	350	1.0	271	2.5	154	3.3	338	4.4	209	9.9	230	7.9	234	2.6	169	3.6	293	6.2	343	2.6	286	6.4
2,000	299	2.3	12	1.4	265	1.9	147	3.6	340	2.1	212	7.1	238	7.4	204	2.9	178	3.5	292	7.2	344	3.0	281	7.0
2,500	289	2.6	311	1.0	315	2.0	130	4.2	308	1.8	210	5.3	237	7.6	191	5.9	213	2.4	290	7.5	308	2.5	274	7.9
3,000	273	3.2	283	2.1	349	1.6	134	3.2			209	3.1	241	8.1	198	8.5	241	3.1	297	7.7	286	3.2	277	9.1
4,000	243	3.2	296	4.5	17	3.6	72	3.2			245	1.8	231	7.1	200	10.8	237	6.0	288	8.2	292	3.9	274	7.3
5,000							50	3.9					298	5.8	216	8.6	222	8.3	290	8.4	263	4.9		

RIVERS AND FLOODS

By Richmond T. Zoch

[River and Flood Division, Montrose W. Hayes, in charge]

In June there was a number of overflows in the Southeastern States as well as some in Iowa, Kansas, and in Washington. Those in the Southeastern States were of minor importance.

HEAVY RAINFALL OF JUNE 7–8, 1934
VICINITY OF SIOUX CITY, IOWA

Fig. 1

Heavy general rains over the Floyd River watershed on the afternoon of June 7, 1934, and continuing during the night of the 7th and 8th, caused the greatest flood in that stream since May 1892. At Sioux City the crest stage was 0.8 foot higher than in the destructive flood of September 1926. The rainfall was much heavier in 1926 in Sioux County, Iowa, and consequently the damage in that county was much less in 1934. The area of heavy rainfall (see fig. 1) was more widespread in 1934, when it extended over the entire watershed. At most stations well over half of the precipitation occurred within a 15-hour period, beginning on the afternoon of June 7, and in several instances half of the rain fell in one or two heavy thunderstorms that lasted about an hour each.

The progress of the 1934 flood is shown in figure 2. The flood crest moved much faster in 1934 than in 1926, thus it moved from Merrill to the Missouri River, a distance of 22.8 miles in 25 hours in 1926, while in 1934 the same distance was covered in 18 hours. This difference was no doubt in part due to the retarding influence of the more advanced vegetation in 1926.

The same storm which caused the flood in the Floyd River also caused floods in the Big Sioux River and Perry Creek. The flood in Perry Creek was the highest and most destructive since 1909.

While the flood in the Big Sioux was a damaging one it was not as destructive as those in Perry Creek and the Floyd River.

Table of flood stages in June 1934

[All dates are in June, unless otherwise specified]

River and station	Flood stage	Above flood stages—dates From—	Above flood stages—dates To—	Crest Stage	Crest Date
ATLANTIC SLOPE DRAINAGE					
Peedee:	*Feet*			*Feet*	
Cheraw, S.C	27	7	7	28.8	7
Mars Bluff Bridge, S.C	17	8	13	19.0	11
Poston, S.C	18	14	14	18.0	14
Saluda:					
Pelzer, S.C	6	5	8	6.2	6
Chappells, S.C	12	5	10	19.8	7
Broad: Blairs, S.C	14	6	7	14.5	6
Wateree: Camden, S.C	23	9	9	23.8	9
Santee:					
Rimini, S.C	12	May 30	24	17.6	10
		28	30	12.8	29
Ferguson, S.C	12	2	23	13.8	13
Broad: Carlton, Ga	15	3	3	15.2	3
Savannah: Ellenton, S.C	14	5	16	21.9	9
Ogeechee: Dover, Ga	7	4	14	9.1	7
Oconee: Milledgeville, Ga	20	6	6	20.5	6
Altamaha: Charlotte, Ga	12	14	20	13.2	17, 18
EAST GULF OF MEXICO DRAINAGE					
Pearl:					
Jackson, Miss	18	18	23	21.5	21
Monticello, Miss	15	19	20	16.9	19
West Pearl: Pearl River, La	12	26	29	12.6	27
MISSISSIPPI SYSTEM					
Missouri Basin					
Big Sioux: Akron, Iowa	12	8	10	16.1	8
Floyd: Merrill, Iowa	13	7	9	18.4	7
Solomon: Beloit, Kans	18	16	19	24.5	19
Smoky Hill: Lindsborg, Kans	21	20	20	21.5	20
PACIFIC SLOPE DRAINAGE					
Columbia Basin					
Columbia:					
Marcus, Wash	24	Apr. 21	July 23	35.5	2
Vancouver, Wash	15	May 29	14	16.5	5, 6

Warnings were promptly issued for all of these floods and much property was saved as a result. The total damage was more than $500,000. No lives were lost.

The following comments of the official in charge at Portland, Oreg., Weather Bureau office are of interest in connection with the rise in the Columbia River:

The annual rise of the Columbia River in 1934 had some unusual features. Heavy precipitation occurred early in the winter, but in the Pacific Northwest temperatures were unusually high, and most of this precipitation was rain. As a result of this combination the run-off during the winter and early spring was very heavy in comparison with the usual low stages during that part of the year. The opening of spring found a very small snow supply in most of the drainage basin lying within the United States, but there was a rather large snow supply in the mountains of British Columbia and this condition extended southward along the eastern slope of the Cascade Mountains about half-way across the State of Washington. The spring, like the winter, was unusually mild, and melting of snow proceeded accordingly. No high stages were experienced in the Snake and its tributaries, but the Columbia remained rather high through the spring and into June. The highest stages were mostly in the first and second weeks in May. A drop in temperature after that time resulted in a considerable fall; a return to warm weather late in May and early in June resulted in a second crest in most places, but only at one place did this equal the May crest. The flood stage was reached only at Marcus and Vancouver, Wash., and no damage was reported from either place.

The most important duty of this office in this connection was making daily forecasts of stages for the guidance of operations in the construction of the Bonneville Dam, near Portland. This was carried on in such a way that work was not at any time shut down because of high water.

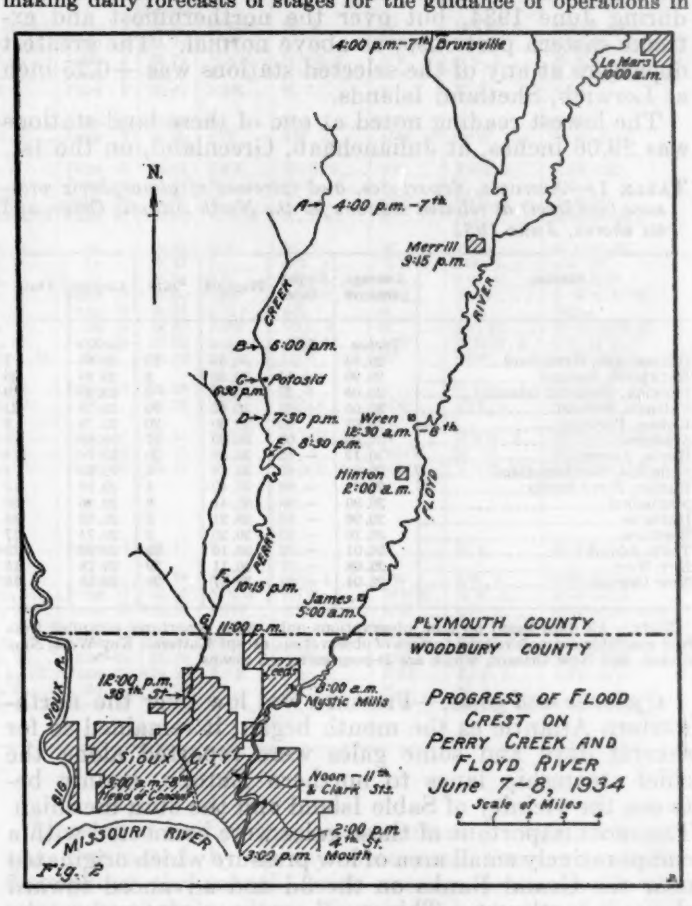

Fig. 2

The tropical disturbance which passed inland over the United States on June 16 caused very heavy rains in western Tennessee, and produced floods in the creeks and small streams, but the larger rivers remained low. The rainfall was most intense in Montgomery and Robertson Counties of Tennessee, Clarksville reporting 6.30 inches and Cedar Hill 10 inches. Considerable damage resulted.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

[The Marine Division, W. F. McDonald in charge]

NORTH ATLANTIC OCEAN

By H. C. HUNTER

Atmospheric pressure.—The pressure averaged less than normal over most parts of the North Atlantic Ocean during June 1934, but over the northernmost and extreme eastern portions, was above normal. The greatest departure at any of the selected stations was +0.25 inch at Lerwick, Shetland Islands.

The lowest reading noted at one of these land stations was 29.06 inches, at Julianehaab, Greenland, on the 1st.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, June 1934*

Station	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.84	-------	30.32	10	29.06	1
Reykjavik, Iceland	29.99	+0.11	30.50	8	29.49	26
Lerwick, Shetland Islands	30.05	+.25	30.40	2	29.48	19
Valencia, Ireland	30.05	+.05	30.42	30	29.78	21
Lisbon, Portugal	30.03	.00	30.20	20	29.79	3
Madeira	30.05	−.02	30.20	27	29.69	3
Horta, Azores	30.12	−.12	30.48	20	29.74	14
Belle Isle, Newfoundland	29.84	.00	30.18	4	29.10	1
Halifax, Nova Scotia	29.91	−.06	30.40	4	29.58	15
Nantucket	29.90	−.08	30.41	8	29.46	20
Hatteras	29.96	−.05	30.21	8	29.63	18
Bermuda	30.10	−.03	30.26	3	29.74	17
Turks Island	30.01	−.02	30.15	29	29.93	19
Key West	29.98	−.01	30.11	29	29.78	15
New Orleans	29.94	−.04	30.17	29	29.51	16

NOTE.—All data based on a.m. observations only, with departures compiled from best available normals related to time of observation, except Hatteras, Key West, Nantucket, and New Orleans, which are 24-hour corrected means.

Cyclones and gales.—Pressure was low over the northwestern Atlantic as the month began; it remained so for several days and some gales were reported along the chief steamship lanes to northern Europe, mainly between the vicinity of Sable Island and the 30th meridian. The most important of these gales were connected with a comparatively small area of low pressure which originated near the Grand Banks on the 3d and advanced toward the east-northeast. This small area was centered on the evening of the 3d near 40° N., 51° W., approximately the location of the German liner *Europa*, which encountered wind of force 11 from the north, at 8 p.m. Another German steamer, the *Berlin*, reported wind of force 12, also from the north, during the forenoon of the 5th, at about latitude 48° N., longitude 33° W.

After the first week of the month, gales near or to eastward of the region of the Grand Banks were rare and mainly unimportant. The most noteworthy was encountered late on the 21st, not far to southeastward of the *Berlin's* location on the 5th, by the German M.S. *Skagerrak*, which reported a maximum force of 10 from the north.

Tropical disturbance.—As early as the 4th disturbed conditions were noted near the Gulf of Honduras, and by the forenoon of the 8th a well-marked storm was indicated as moving northward, its center being a short distance to eastward of the city of Belize. The movement became more northwestward, and on the 9th the center crossed the tip of the Yucatan peninsula; then in the southwestern part of the Gulf of Mexico it slowly turned a leftward loop. Advancing again toward the north, the storm had attained marked strength by the 15th, and a few vessels, to southward of the eastern section of the Louisiana coast, reported pressures but little above 29 inches. From Louisiana the storm center moved over land in a northeastward course and reached New Jersey on the 19th, thence it was sometimes over water as it traveled to Nova Scotia and the north shore of the Gulf of St. Lawrence.

Several reports of gales connected with this storm have been received from the Gulf of Honduras to near the coast of New Jersey. The most notable of these was from the British S.S. *Author*, which about latitude 21° N., longitude 93° W., during the night of the 12–13th, met "heavy squalls of hurricane force". However, as far as reports at hand indicate, the marine losses in connection with this storm were of small importance.

Chart VIII shows the situation on the 16th, when the storm center was near the Louisiana coast line.

Fog.—On the whole, fog during June was less prevalent over the North Atlantic than it had been during May. The chief exception was noted from near Nova Scotia to the vicinity of New York Bay, where a considerable increase in the amount of fog was reported. Here the part of the month with least fog was the 15th to 22d. The 5-degree square of 40°–45° latitude, 65°–70° longitude experienced fog on 21 days.

In the general region of the Grand Banks the first 10 days of the month had comparatively little fog. For the whole month the square from 40°–45° latitude, 45°–50° longitude recorded the greatest number of days with fog in this region, namely 16.

A collision on the 4th, near the entrance to New York Harbor, and another upon Point Judith, R.I., breakwater on the 7th were attributed to fog. There was considerable damage in each instance, but no loss of life.

Trans-Atlantic aviation.—Early on June 29 the Adamowicz brothers started by airplane from Harbor Grace, Newfoundland, to descend 30 hours later in northwestern France, near Flers. The weather situation on the 29th is shown by chart IX.

OCEAN GALES AND STORMS, JUNE 1934

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
Scanpenn, Am. S.S.	Copenhagen	Philadelphia	42 12 N.	56 42 W.	June 1	8a, June 1	June 1	29.84	WSW	W, 4	W	WSW, 8	WSW-W.
Europa, Ger. S.S.	New York	Cherbourg	40 22 N.	50 52 W.	June 3	8p, 3	June 4	29.74	NW	N, 11	NNE	N, 11	NW-N-NNE.
Effingham, Am. S.S.	New Orleans	London	40 30 N.	49 40 W.	do	9p, 3	June 3	29.74	NNE	NNE, 7	NE	NE, 9	N-NE.
Berlin, Ger. S.S.	Cobh	Halifax	48 12 N.	33 02 W.	June 5	6a, 5	June 5	29.13	E	NNE, 12	WNW	N, 12	E-NNE-WNW.
Carillo, Am. S.S.	Puerto Barrios.	New York	17 35 N.	87 10 W.	June 4	6p, 6	June 6	29.61	ESE	E, 7	E	E, 7	None.
Exermont, Am. S.S.	Lisbon	do	42 33 N.	36 00 W.	June 6	9p, 6	do	29.59	S	S, 9	SSW	S, 9	S-W.
Poseidon, Du. S.S.	English Channel.	San Juan	41 20 N.	32 05 W.	June 7	10a, 7	June 7	29.61	SW	SW, 8	NW	SSW, 10	SSW-NW
Silvercedar, Br. M.S.	Houston	Colon	21 11 N.	86 05 W.	June 8	2a, 9	June 10	29.83	ESE	ESE, 9	SE	ESE, 9	ESE-SE.
Sixaola, Am. S.S.	New Orleans	Tela	19 26 N.	86 32 W.	do	4a, 9	June 9	29.64	E	SSE, 10	S	E, 10	SE-S.
Darien, Pan. S.S.	Mobile	Belize	20 24 N.	86 12 W.	do	do	June 10	29.71	E	E, 8	SSE	ESE, 9	E-ESE.
Wawa, Hond. S.S.	A. Obregon, Mexico.	Galveston	23 13 N.	93 59 W.	June 9	Noon, 10	June 11	29.59	WNW	N, 7	E	NE, 7	NW-N-NE.
Morazan, Hond. S.S.	New Orleans	Vera Cruz	20 40 N.	95 20 W.	June 10	2a, 11	do	29.51	NE	W, 8	W	W, 9	WNW-W.
Oriente, Am. S.S.	New York	do	19 30 N.	94 12 W.	do	5a, 11	do	29.47	S	SW, 8	WNW	SW, 9	SW-W.
Heddernheim, Ger. S.S.	Houston	Bremen	39 21 N.	52 27 W.	June 11	2p, 11	do	29.74	SW	SW, 8	W	SW, 9	SW-NW.
Author, Br. S.S.	Belize	Vera Cruz	[1] 21 10 N.	[1] 92 46 W.	June 12	4a, 13	June 13	[2] 29.00	SSE	WNW, 8	W	S, 12	S-WNW-W.
A. C. Bedford, Am. S.S.	Port Aransas	New York	26 00 N.	88 50 W.	June 14	5a, 15	June 15	29.34	ENE	SE, 7	S	S, 8	None.
Tegucigalpa, Hond. S.S.	New Orleans	Vera Cruz	28 18 N.	90 00 W.	June 16	6a, 16	June 16	29.43	ESE	SSE, 9	S	SE, 10	ESE-SSE-S.
Maiden Creek, Am. S.S.	Avonmouth	Mobile	32 43 N.	54 23 W.	June 18	4a, 18	June 18	29.62	SW	SW, 7	NW	WNW, 8	SW-NW.
Greystoke Castle, Br. MS.	Gibraltar	New York	38 06 N.	45 31 W.	do	Noon, 18	do	29.82	SSW	SSW, 8	W	SSW, 8	SSW-W.
Breedyk, Du. S.S.	Rotterdam	Baltimore	37 08 N.	73 35 W.	June 19	1a, 19	June 19	29.56	S	S, 8	S	S, 8	SSE-S.
F. Q. Barstow, Am. S.S.	Corpus Christi.	Boston	36 55 N.	72 40 W.	June 18	8p, 19	do	29.75	SE	SE, 8	NW	SSE, 8	SE-NW.
Colytto, Du. S.S.	Montreal	London	50 08 N.	13 55 W.	June 21	1p, 21	June 21	29.86	WSW	WSW, 8	W	WSW, 8	WSW-W.
Skagerrak, Ger. M.S.	Liverpool	Port Arthur	46 40 N.	31 14 W.	do	9p, 21	June 22	29.70	N	N, 5	NNE	N, 10	None.
Leto, Du. S.S.	Swansea	Montreal	51 54 N.	54 42 W.	June 30	1p, 30	June 30	29.19	E	NNE, 8	NNW	NNE, 8	NNE-NNW.
NORTH PACIFIC OCEAN													
Dorothy Luckenbach, Am. S.S.	Los Angeles	Balboa	17 24 N.	101 54 W.	June 4	2a, 4	June 4	29.75	E	E, 8	E	E, 8	E-SE.
Slemmestad, Nor. M.S.	do	Yokohama	35 15 N.	[1] 143 30 E	do	9p, 4	do	29.68	SSW	SW, 4	SW	SW, 9	SW-WSW.
Pres. Jackson, Am. S.S.	Yokohama	Victoria, B.C.	[1] 48 15 N.	125 30 W.	June 11	10p, 11	June 11	29.85	NNW	SSW, 5	WNW	NW, 8	NW-SSW.
Taisei Maru, Jap. S.S.	do	Portland, Oreg.	36 30 N.	152 00 E.	June 17	9p, 17	June 17	[2] 29.26	SSW	SW, 9	NW	SW, 9	SSW-SW-NW.
Bronxville, Nor. M.S.	Dairen	Los Angeles	38 53 N.	148 40 E.	do	11a, 17	June 18	[2] 29.49	ESE	E, 6	NNW	ENE, 8	ESE-ENE.
Golden Star, Am. S.S.	San Francisco	Yokohama	35 48 N.	141 54 E.	June 20	2p, 21	June 21	29.66	SSW	SW, 9	SW	SW, 9	SSW-SW.
Bronxville, Nor. M.S.	Darien	Los Angeles	45 40 N.	173 20 E.	June 22	11 p, 22	June 22	[2] 29.25	ESE	Var. 1	ESE	ESE, 8	ESE-NW.
Bonneville, Nor. M.S.	Manila	do	34 55 N.	121 33 W.	do	4a, 23	do	29.98	N	N, 5	N	N, 8	
San Julian, Am. S.S.	Shanghai	Portland, Oreg.	48 06 N.	178 06 E.	June 23	Noon, 23	June 23	29.09	E	N, 6	NW	E, 9	E-N-NNW.

[1] Position approximate.
[2] Barometer uncorrected.

NORTH PACIFIC OCEAN, JUNE 1934

By WILLIS E. HURD

Atmospheric pressure.—The average pressure over the North Pacific Ocean during June 1934 was generally close to normal, although over the central Aleutians, at Dutch Harbor, the June average of 29.80 was 0.10 inch below. The Aleutian cyclone, though shallow, was thus indicated as persisting into early summer.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean, June 1934, at selected stations*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Point Barrow	29.89	−0.10	30.30	11, 12	29.18	20
Dutch Harbor	29.80	−.10	30.52	29	29.38	6
St. Paul	29.84	−.02	30.54	29	29.28	1
Kodiak	29.87	−.04	30.36	30	29.46	2, 20
Juneau	29.98	−.03	30.39	8	29.46	21
Tatoosh Island	30.07	+.05	30.40	29	29.75	5
San Francisco	29.91	−.05	30.05	7	29.62	5
Mazatlan	29.85	+.02	29.98	19	29.72	12, 13
Honolulu	30.04	.00	30.12	19	29.92	6
Midway Island	30.08	+.03	30.20	19, 20, 24	29.76	7
Guam	29.90	+.03	29.94	[1] 6	29.80	28, 29
Manila	29.81	−.01	29.86	6, 12, 15	29.76	20, 23, 24, 30
Hong Kong	29.75	----------	29.87	14	29.62	19
Naha	29.84	+.09	29.96	14	29.70	9, 18
Chichishima	29.95	+.04	30.10	14	29.82	28
Nemuro	29.86	----------	30.08	10	29.56	27

[1] And on 7 other dates.

NOTE.—Data based on 1 daily observation only, except those for Juneau, Tatoosh Island, San Francisco, and Honolulu, which are based on 2 observations. Departures are computed from best available normals related to time of observation.

More than half of the ocean south of the northern LOW was dominated by anticyclonic conditions practically throughout the month, with average pressures for the most part slightly plus. In middle latitudes of the Far East, where anticyclones are unusual in June, pressure, though low, was somewhat above the normal, with a maximum plus departure of 0.09 inch at Naha, Nansei Islands.

Cyclones and gales.—June 1934 was one of the proverbially quite months on the north Pacific. Depressions as a rule were of moderate depth only, and unaccompanied by severe gales. The highest wind force recorded was 9, occurring on 4 days, mostly in Japanese waters. The lowest corrected barometer reading of the month was 29.09 inches, reported by the American S.S. *San Julian*, near 48° N., 178° E., on the early morning of the 23d, accompanied by fresh to strong gales.

Gales equalling or exceeding force 8, as indicated by present information, were comparatively few. These occurred east of Honshu on the 4th, 17th, and 21st; south of the western Aleutians on the 22d and 23d; near Vancouver Island on the 11th; off the California coast on the 22d; and off the Mexican coast west of Acapulco on the 4th.

In the Central American Pacific area the weather was disturbed from the 4th to 8th, owing to a depression which, during these days, affected both the west and the Caribbean coasts. The only gale noted as occurring in Pacific waters during the progress of the disturbance, was the fresh gale of the 4th near Acapulco, but rainfall

in places was torrential. A report from the French S.S. *San Diego* said that on the 14th, "about 25 miles off the coasts of Guatemala and Salvador numerous big trees were met", which it was believed by the observer, were uprooted and washed to sea as a result of the disturbed conditions of the preceding week.

Fog.—The percentage of days with fog was below the normal for the month over most parts of the ocean. The American coast had less fog in June 1934 than in any previous month since December 1932. There were 2 days with fog off the southern end of Lower California, and 1 day with fog noted along the entire coast northward to Alaska. Along the northern shipping routes, between 135° W. and Japan, there were 3 to 7 or more days with fog in individual 5-degree squares, with the greatest number occurring south and east of the Kuril Islands. Over the western half of the central trans-Pacific routes fog diminished southward to the vanishing point at about 25° N.

CLIMATOLOGICAL TABLES [1]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, June 1934

[For description of tables and charts, see REVIEW, January, p. 37]

Section	Temperature: Section average	Temperature: Departure from the normal	Monthly extremes: Station	Highest	Date	Monthly extremes: Station	Lowest	Date	Precipitation: Section average	Precipitation: Departure from the normal	Greatest monthly: Station	Amount	Least monthly: Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	80.1	+1.8	Decatur	105	27	St. Bernard	52	21	4.79	+0.46	Centerville	10.20	Lock No. 3	1.29
Arizona	73.8	−4.3	5 stations	114	[1] 29	Fort Valley	22	7	.19	−0.12	Sacaton	.75	14 stations	.00
Arkansas	81.1	+4.0	Ozark	108	30	Dutton	49	20	2.88	−1.11	Hot Springs	6.71	Jonesboro	.70
California	65.6	−2.5	Greenland Ranch	122	30	Twin Lakes	20	3	.74	+.41	Shield's Ranch	4.58	9 stations	.00
Colorado	64.3	+2.8	Las Animas	106	8	Hermit	16	8	.94	−.47	Sedgwick	5.40	Fruita	.06
Florida	80.2	+.4	Mount Pleasant	103	21	2 stations	59	1	10.22	+3.52	St. Leo	24.26	Pensacola	1.25
Georgia	79.6	+1.5	Washington	103	28	Blairsville	49	12	5.08	+.64	Clayton	14.20	Louisville	1.23
Idaho	60.5	+.2	Orofino	102	11	Warren	21	1	1.48	+.26	Moscow	4.15	Richfield	.12
Illinois	78.8	+7.1	2 stations	108	[1] 28	Mount Carroll	45	13	3.03	−1.03	Galesburg	6.28	Grand Chain	.70
Indiana	77.5	+6.0	Collegeville	109	1	2 stations	43	14	3.55	−.26	Washington	9.34	Howe	.97
Iowa	77.2	+7.6	Lamoni	111	20	Boone (near)	43	12	3.49	−1.12	Akron	9.13	Ames	1.24
Kansas	80.5	+6.7	3 stations	110	[1] 23	Oberlin	47	18	2.73	−1.24	Alton	7.14	Deerfield (near)	.32
Kentucky	77.4	+3.5	2 stations	105	28	4 stations	50	[1] 13	4.58	+.46	Hopkinsville	8.15	Whitesburg	.76
Louisiana	81.8	+1.8	5 stations	103	[1] 19	2 stations	60	[1] 1	4.80	+.15	Franklin	15.73	Natchitoches	.01
Maryland-Delaware	74.7	+3.9	Baltimore, Md.	105	29	Oakland, Md.	42	15	3.25	−.70	Grantsville, Md.	5.84	Bridgeville, Del.	1.36
Michigan	68.3	+4.7	Houghton Lake	107	1	Munising	30	7	2.18	−.94	Cooke Site	5.22	Adrian	.63
Minnesota	67.4	+2.4	New London	108	27	2 stations	34	[1] 7	4.02	−.03	Red Lake Falls	7.57	Zumbrota	1.90
Mississippi	81.0	+2.2	Columbus	103	[1] 26	3 stations	57	[1] 13	5.65	+1.48	Cleveland	11.44	Bay St. Louis	1.38
Missouri	80.4	+6.8	4 stations	108	[1] 23	Goodland	47	19	2.85	−1.90	Caruthersville	5.95	Farmington	.23
Montana	60.2	+.4	Mildred	102	26	Conways Ranch	24	[1] 2	2.99	+.47	Babb (near)	7.55	Sarpy Creek	.30
Nebraska	74.9	+5.9	Falls City	109	29	2 stations	37	[1] 9	3.07	−.69	Hartington	6.52	North Loup	.68
Nevada	63.0	−1.3	Logandale	116	30	Zorra Vista Ranch	19	3	.91	+.41	Marlette Lake	2.45	2 stations	.00
New England	65.2	+1.4	Waterbury, Conn.	101	29	Pittsburg, N.H.	26	8	4.49	+1.13	Adams, Mass.	7.41	Lakeport, N.H.	2.08
New Jersey	72.6	+3.8	Belvidere	103	29	Layton	38	8	3.68	−.03	Long Valley	6.41	Northfield	1.64
New Mexico	69.8	+.9	Oro Grande	112	[1] 11	Horse Springs	18	7	.52	−.73	Fort Sumner	2.13	4 stations	.00
New York	68.4	+3.5	Geneva	102	2	Indian Lake	25	8	3.54	−.09	Bainbridge	7.18	Fredonia	1.44
North Carolina	76.1	+2.2	High Point	105	28	Banners Elk	43	15	4.89	+.15	Highlands	13.63	Manteo	1.14
North Dakota	64.3	+1.8	Hankinson	100	2	Garrison	29	11	3.04	−.41	Wahpeton	5.52	Powers Lake	1.09
Ohio	76.0	+6.5	Germantown	108	29	Millport	43	14	3.52	−.25	Mt. Vernon (near)	7.47	Catawba Island	.88
Oklahoma	82.6	+5.4	Hollis	113	22	Kenton	48	8	2.45	−1.32	Camargo	6.90	Waurika	.24
Oregon	59.8	+.3	Arlington	105	11	Lake	20	4	1.53	+.31	Cove	4.84	Big Eddy	.00
Pennsylvania	72.9	+5.0	Marcus Hook	104	30	Brookville	35	8	3.64	−.54	Coatesville	6.15	Catawissa	1.12
South Carolina	78.9	+1.5	2 stations	103	[1] 23	Long Creek	52	14	4.92	+.15	Newberry	12.05	Beaufort (near)	1.04
South Dakota	70.5	+3.9	Sisseton	105	2	Clark	37	11	3.35	−.19	Vermillion	7.87	Wood	.83
Tennessee	77.5	+2.8	2 stations	103	[1] 26	Erwin	39	1	5.25	+1.01	Cedar Hill	12.08	Tiptonville	1.57
Texas	83.9	+3.7	Snyder	114	20	3 stations	52	[1] 1	.81	−2.39	Clarendon	3.85	24 stations	.00
Utah	63.9	−.6	St. George	108	30	Soldier Summit	23	2	.51	−.06	Ogden	1.81	Loa	T
Virginia	75.5	+3.9	Lincoln	107	29	Burkes Garden	38	14	3.53	−.63	Stuart	7.72	Emporia	1.67
Washington	61.8	+1.4	3 stations	105	11	2 stations	25	2	.67	−.92	Mount Baker Lodge	3.83	White Swan	.00
West Virginia	74.3	+4.7	Martinsburg	106	29	3 stations	41	[1] 13	3.45	−.90	Pickens	6.78	Martinsburg	1.36
Wisconsin	69.2	+4.0	2 stations	106	1	Cornucopia	32	7	4.02	−.01	Neillsville	8.15	Milwaukee (Airport)	1.46
Wyoming	59.8	+1.2	Colony	100	26	South Pass City	18	2	1.83	+.21	Bechler River	5.50	Riverton	.20
Alaska (May)	42.6	−.2	Wrangell	82	22	Kotzebue	0	6	1.73	+.14	Cordova	16.38	Barrow	T
Hawaii	74.5	+1.0	Hahaione Valley	93	[1] 17	Kanalohuluhulu	50	[1] 1	7.36	+2.45	Puohakamoa No. 2	38.00	4 stations	.00
Puerto Rico	79.7	−.6	Manati	96	7	Guineo Reservoir	48	18	4.42	−1.82	Coloso	14.60	Morovis	1.25

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, June 1934*

[Compiled by Annie E. Small]

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max.+mean min.÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
New England							64.8	+1.3										76	3.27	+0.3										5.5		
Eastport	76	67	85	29.81	29.89	-0.04	54.8	-0.3	84	29	63	41	8	47	34	51	48	82	3.33	+.4	15	6,675	sw.	32	se.	20	5	10	15	6.6	0.0	0.0
Greenville, Maine	1,070	6	40	28.73	29.88		58.4	----	84	6	68	32	8	49	32				6.45	----	18	3,745	se.	23	----	29	7	9	14	----	.0	.0
Portland, Maine	103	82	117	29.77	29.89	-.06	63.0	+.5	90	29	71	47	8	55	29	56	52	72	3.51	+.2	16	6,340	sw.	24	nw.	6	15	9	6	4.3	.0	.0
Concord	289	60					65.5	+2.6	95	2	77	39	8	54	43				4.09	+.9	12	----	nw.				10	13	7		.0	.0
Burlington	403	11	48	29.44	29.87	-.09	65.4	-.3	91	5	76	37	8	55	34				3.81	+.4	12	6,545	s.	32	s.	9	8	15	7	5.3	.0	.0
Northfield	876	12	60		29.88	-.08	62.5	+1.2	91	2	75	30	8	50	44			77	2.31	-.9	12	5,273	s.	23	sw.	24	4	19	7	6.0	.0	.0
Boston	124	336	360	29.76	29.89	-.07	66.9	+.4	94	29	76	50	9	58	33	60	56	72	3.11	+.2	15	9,448	sw.	39	e.	19	10	13	7	5.5	.0	.0
Nantucket	12	14	90	29.89	29.90	-.06	63.2	+2.2	82	30	70	49	8	56	19	59	57	86	2.33	-.3	9	9,579	sw.	34	sw.	29	9	12	9	5.7	.0	.0
Block Island	26	11	46	29.87	29.90	-.07	63.6	+1.8	81	30	70	50	8	58	18	60	59	87	3.31	+.7	7	9,894	sw.	38	se.	19	5	15	10	6.0	.0	.0
Providence	160	215	251	29.73	29.90	-.07	68.7	+.4	96	29	78	48	8	59	33	61	56	67	3.33	+.6	12	7,827	nw.	32	nw.	10	16	8	6	4.3	.0	.0
Hartford	159	70	104		29.89	-.08	69.6	+2.5	98	29	80	44	8	59	32				3.46	+.4	8	5,754	s.				9	13	8		.0	.0
New Haven	106	74	153	29.80	29.90	-.07	70.0	+3.4	99	29	79	48	8	61	33	62	58	70	3.42	+.3	7	6,396	s.	27	n.	10	5	16	9	5.8	.0	.0
Middle Atlantic States							74.4	+4.0										71	3.31	-0.3										5.3		
Albany	97	107	115	29.78	29.88	-.09	69.8	+1.8	94	21	80	46	8	60	32	63	59	71	5.75	+2.4	14	5,875	s.	27	nw.	6	7	15	8	5.5	.0	.0
Binghamton	871	60	68	28.99	29.90	-.07	69.7	+4.1	92	3	80	44	8	59	32				3.70	+.3	11	4,146	nw.	29	sw.	3	2	13	15	7.0	.0	.0
New York	314	415	454	29.57	29.90	-.08	72.4	+3.6	97	29	80	57	4	64	31	64	59	70	3.21	-.1	9	9,553	sw.	38	nw.	19	7	16	7	5.8	.0	.0
Bellefonte	1,050	5	42	28.82	29.90		70.2		96	29	83	39	8	58	37	64	61	71	4.35		9		sw.				6	15	9	6.0	.0	.0
Harrisburg	374	94	104	29.50	29.89	-.10	74.4	+4.1	100	29	84	53	8	65	29	66	61	67	3.52	-.1	9	5,223	w.	27	w.	22	8	19	3	5.1	.0	.0
Philadelphia	114	123	367	29.79	29.92	-.06	76.2	+4.8	102	29	85	59	9	67	30	67	62	66	3.22	.0	9	8,620	sw.	35	sw.	10	8	17	5	5.5	.0	.0
Reading	323	283	306	29.56	29.90		74.0	+4.2	99	29	83	55	8	65	25	66	61	67	2.02	-1.5	9	7,592	nw.	43	se.	19	5	21	4	5.5	.0	.0
Scranton	805	72	104	29.06	29.90	-.08	71.3	+3.5	93	29	82	47	8	61	33	64	60	69	2.45	-1.2	10	5,099	sw.	19	n.	19	4	19	7	5.2	.0	.0
Atlantic City	52	37	172	29.86	29.92	-.06	70.7	+4.1	89	25	77	55	8	64	23	66	63	82	2.48	-.6	7	10,981	s.	50	se.	19	8	13	9	5.7	.0	.0
Sandy Hook	22	10	57	29.88	29.90		71.2		96	29	79	55	4	64	30	65	63	78	3.40	-.4	10	8,595	sw.	36	nw.	19	11	11	8	4.7	.0	.0
Trenton	190	88	106	29.70	29.90		73.5	+4.0	100	29	84	53	8	63	32	66	61	70	3.41	+.3	8	6,714	s.	27	nw.	12	5	20	5	5.7	.0	.0
Baltimore	123	100	215	29.78	29.90	-.09	77.8	+5.1	105	29	87	62	9	69	29	69	64	65	5.39	+1.5	10	7,389	sw.	36	se.	19	12	12	6	4.8	.0	.0
Washington	112	62	85	29.79	29.90	-.10	77.2	+5.0	101	29	87	61	15	68	27	69	65	68	2.87	-1.3	10	4,556	sw.	34	nw.	22	13	13	4	4.4	.0	.0
Cape Henry	18	8	54	29.92	29.94		78.2	+5.3	100	27	87	64	1	70	29	71	68	77	2.82	-1.1	10	7,585	sw.	49	nw.	27	11	17	2	4.4	.0	.0
Lynchburg	686	5	----	29.21	29.94	-.07	76.8	+2.2	104	29	89	53	14	64	35				4.21	+.4	10		s.				4	23	3		.0	.0
Norfolk	91	170	205	29.85	29.95	-.05	78.8	+4.4	98	30	88	63	9	69	26	71	68	75	1.68	-2.5	10	8,507	s.	44	nw.	30	6	14	10	5.9	.0	.0
Richmond	144	11	52	29.79	29.94	-.07	78.1	+4.0	98	29	88	59	9	68	26	70	67	74	3.65	-.2	10	5,278	sw.	30	nw.	30	11	14	5	4.3	.0	.0
Wytheville	2,304	49	55	----	29.92	-.09	71.7	+3.0	95	26	82	50	14	61	36	----	----	70	2.47	-1.7	8	4,230	w.	21	s.	29	9	12	9	----	.0	.0
South Atlantic States							78.8	+2.1										77	4.58	0.0										4.8		
Asheville	2,253	89	104	27.69	29.97	-.04	72.6	+3.9	94	25	84	54	14	61	34	65	62	78	5.50	+1.6	14	4,229	nw.	25	n.	23	11	11	8	5.1	.0	.0
Charlotte	779	244	267	29.14	29.96	-.05	77.8	+2.3	96	27	87	61	2	69	25	68	64	70	7.36	+3.1	12	7,336	sw.	34	nw.	23	10	11	9	5.0	.0	.0
Greensboro	886	6	56	29.02	29.96	----	76.8	----	98	29	88	59	14	66	32	69	66	74	3.19	----	12	5,232	sw.	27	nw.	23	9	10	11	5.4	.0	.0
Hatteras	11	5	50	29.95	29.96	-.05	77.5	+1.9	87	19	82	68	9	73	18	73	72	83	2.36	-2.2	10	8,299	sw.	35	s.	18	15	9	6	4.0	.0	.0
Raleigh	376	103	146	29.55	29.94	-.07	78.8	+3.1	98	30	89	60	1	69	27	71	68	75	5.05	+.7	11	5,777	sw.	32	nw.	23	9	11	10	5.3	.0	.0
Wilmington	72	73	107	29.91	29.98	-.03	78.5	+1.7	92	26	86	66	2	71	25	73	71	82	3.42	-1.7	13	6,785	sw.	26	s.	18	11	11	8	5.0	.0	.0
Charleston	48	11	92	29.94	29.99	-.02	80.6	+1.7	94	11	87	66	1	74	20	76	74	84	1.68	-2.9	8	6,958	s.	25	sw.	12	12	12	6	4.5	.0	.0
Columbia, S.C.	351	41	57	29.60	29.97	-.04	80.3	+2.2	99	29	90	63	2	70	27	71	68	73	3.30	-.9	9	4,890	s.	25	sw.	18	15	7	8	4.4	.0	.0
Augusta	182	62	77	29.76	29.96	-.05	80.8	+2.1	98	23	91	62	1	70	27	72	69	72	1.68	-3.0	11	3,995	s.	21	nw.	10	13	10	7	4.6	.0	.0
Savannah	65	73	152	29.91	29.98	-.03	80.7	+1.7	97	23	89	65	1	72	24	74	72	80	2.19	-3.1	8	6,565	s.	30	e.	24	14	10	6	4.6	.0	.0
Jacksonville	43	86	110	29.95	30.00	-.01	80.7	+.8	95	23	88	64	1	73	23	74	72	81	13.23	+7.9	12	5,119	se.	26	sw.	24	10	16	4	5.1	.0	.0
Florida Peninsula							81.3	+0.6										79	8.85	+2.6										6.3		
Key West	22	10	64	29.94	29.96	-.03	82.5	+.6	90	22	87	72	24	78	15	76	74	78	2.84	-1.4	10	6,874	se.	22	se.	9	6	13	11	6.1	.0	.0
Miami	25	124	168	29.97	30.00	.00	80.5	+.5	93	20	86	70	6	75	22	75	73	78	9.56	+2.7	18	7,082	se.	27	s.	14	2	10	18	7.6	.0	.0
Tampa	35	88	197	29.95	29.98	-.03	80.8	+.6	93	23	88	67	1	74	23	74	72	81	15.92	+8.7	15	7,081	se.	37	se.	6	8	18	4	5.2	.0	.0
Titusville	43	5	36	29.95	30.00	----	80.2	----	96	20	89	63	1	72	26	----	----	----	7.08	+.3	13	----	se.	----	----	----	9	11	10	----	.0	.0
East Gulf States							80.3	+1.7										75	4.81	+0.2										4.7		
Atlanta	1,173	190	198	28.76	29.97	-.04	78.0	+2.0	95	27	87	61	14	69	25	69	65	70	4.19	+.4	11	5,371	se.	27	sw.	17	10	13	7	5.1	.0	.0
Macon	370	79	87	29.58	29.97	-.04	79.8	+.9	97	23	89	64	21	70	27	71	68	72	1.93	-2.1	11	4,305	s.	26	s.	11	12	11	7	4.4	.0	.0
Thomasville	273	49	58	29.70	29.90	-.01	80.3	+.8	95	23	90	65	2	71	25	74	72	81	5.29	-.2	13	----	sw.	----	----	----	5	14	11	----	.0	.0
Apalachicola	35	11	51	29.93	29.97	----	80.6	----	96	24	86	71	3	75	21	75	----	----	7.10	+1.5	12	----	s.	----	----	----	9	19	2	----	.0	.0
Pensacola	56	149	185	29.91	29.97	-.02	80.0	+.7	93	24	85	65	1	75	22	75	73	80	1.25	-3.4	6	7,889	s.	30	s.	17	10	19	1	4.2	.0	.0
Anniston	741	9	57	----	----	----	78.4	+3.4	98	25	90	57	20	67	35	----	----	----	4.69	+.6	12	----	sw.	----	----	----	9	12	9	----	.0	.0
Birmingham	700	11	48	29.20	29.95	-.04	79.6	+1.7	97	25	89	64	15	70	26	70	67	73	7.60	+3.1	12	4,106	s.	29	se.	29	10	14	6	4.9	.0	.0
Mobile	57	125	161	29.88	29.94	-.05	81.1	+.8	95	18	88	65	1	74	28	74	72	78	4.14	-1.3	12	6,022	s.	45	nw.	18	6	19	5	5.2	.0	.0
Montgomery	218	92	105	29.72	29.96	-.04	81.4	+1.8	98	25	91	67	2	72	25	72	69	73	3.33	-.5	13	4,260	s.	27	n.	18	14	8	8	4.7	.0	.0
Meridian	375	67	92	29.56	29.94	-.04	81.1	+3.0	97	26	92	66	3	71	29	72	70	75	4.52	.0	10	3,880	w.	26	s.	17	14	10	6	4.1	.0	.0
Vicksburg	247	65	73	29.68	29.93	-.04	81.0	+2.0	94	27	90	66	6	72	24	73	70	75	8.45	+4.5	11	4,832	se.	31	e.	17	9	17	4	4.7	.0	.0
New Orleans	53	76	84	29.89	29.94	-.04	82.3	+1.7	93	18	89	69	1	75	20	75	72	75	5.24	-.6	16	4,627	se.	24	se.	16	8	18	4	5.0	.0	.0
West Gulf States							83.3	+3.6										67	0.66	-2.9										2.7		
Shreveport	249	92	227	29.65	29.91	-.05	84.2	+3.5	101	19	94	70	16	74	27	72	68	63	.95	-2.6	2	6,350	s.	29	s.	4	21	8	1	2.5	.0	.0
Bentonville	1,303	11	44	28.54	29.86	-.08	79.6	+5.5	98	28	92	58	19	68	33	----	----	----	2.53	----	6	3,890	sw.	18	s.	10	15	11	4	----	.0	.0
Fort Smith	457	79	94	29.41	29.87	-.07	84.0	+6.5	103	20	96	65	11	72	32	71	65	59	.99	-2.7	4	5,064	e.	30	se.	2	18	10	2	3.2	.0	.0
Little Rock	357	94	102	29.55	29.91	-.05	81.2	+3.8	98	27	91	66	2	71	29	72	68	67	3.17	-.6	5	5,186	s.	28	nw.	17	19	9	2	2.8	.0	.0
Austin	605	136	148	29.24	29.87	----	84.6	+3.4	101	17	96	65	1	74	29	72	66	60	.20	-2.2	3	5,991	se.	28	n.	17	19	10	1	2.8	.0	.0
Brownsville	57	88	96	29.79	29.85	----	82.4	.0	98	18	90	68	15	75	24	75	72	78	.27	-2.6	3	7,816	se.	23	ne.	10	20	10	0	2.8	.0	.0
Corpus Christi	20	11	78	29.88	29.90	-.01	82.6	+1.6	95	16	88	73	15	77	19	76	74	78	.34	-2.2	2	8,372	se.	22	se.	20	20	9	1	3.0	.0	.0
Dallas	512	220	227	29.34	29.87	----	84.0	----	100	19	94	67	3	74	28	70	64	55	.10	-3.8	1	8,458	se.	38	ne.	11	23	5	2	1.9	.0	.0
Fort Worth	670	106	114	29.19	29.90	-.02	86.0	+6.1	102	19	97	69	1	75	33	----	----	----	T	-3.4	0	7,442	s.	24	sw.	17	28	2	0	1.1	.0	.0
Galveston	54	106	114	29.86	29.92	-.03	83.0	+2.3	96	16	87	75	1	79	16	76	73	75	.01	-4.4	1	7,860	s.	21	se.	3	24	6	0	1.7	.0	.0
Houston	138	292	314	29.77	29.91	----	83.6	+2.2	100	18	92	70	3	75	23	----	----	----	.12	-4.4	3	7,843	s.	25	s.	28	20	10	0	3.2	.0	.0
Palestine	510	64	72	29.39	29.90	-.04	82.8	+3.8	100	19	93	66	3	72	30	73	69	67	.05	-3.6	2	5,335	s.	23	ne.	11	22	8	0	2.4	.0	.0
Port Arthur	34	58	66	29.88	29.92	----	83.1	----	96	18	90	71	1	76	20	75	72	72	2.20	-2.6	7	5,661	s.	25	n.	16	16	13	1	3.8	.0	.0
San Antonio	693	242	301	29.15	29.85	-.05	85.2	+4.2	103	16	96	67	1	74	28	73	68	62	.18	-2.3	2	8,594	se.	30	se.	30	14	15	1	3.3	.0	.0

TABLE 1.—*Climatological data for Weather Bureau stations, June 1934*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max.+mean min.÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Ohio Valley and Tennessee							77.8	+5.0										66	4.32	+0.4										4.7		
Chattanooga	762	71	214	29.16	29.95	−0.05	78.8	+3.4	100	26	90	60	2	68	30	69	66	68	6.19	+2.0	15	4,685	w.	32	e.	30	10	12	8	5.0	0.0	0.0
Knoxville	995	66	84	28.92	29.95	−.05	78.2	+4.2	99	26	90	61	14	67	31	69	65	71	5.08	+1.0	12	3,772	w.	21	w.	12	15	12	3	3.9	.0	.0
Memphis	399	78	86	29.51	29.92	−.05	81.0	+3.4	97	26	90	66	13	73	28	71	66	65	2.96	−.6	7	4,652	sw.	25	n.	10	13	11	6	4.0	.0	.0
Nashville	546	168	191	29.38	29.95	−.04	78.9	+3.3	97	28	90	60	13	68	29	70	66	69	5.79	+1.8	11	5,155	w.	39	nw.	9	7	17	6	5.3	.0	.0
Lexington	989	5					77.0	+4.8	99	28	89	53	13	65	33				4.52	+.5	12		ne.				18	8	4		.0	.0
Louisville	525	188	234	29.37	29.94	−.04	79.3	+4.6	98	28	89	61	14	70	28	69	64	65	4.27	+.4	12	6,347	s.	41	s.	21	12	11	7	4.5	.0	.0
Evansville	431	76	116	29.46	29.92	−.05	80.4	+5.3	97	28	90	63	13	70	26	70	66	67	6.72	+2.7	12	5,551	s.	38	sw.	21	8	17	5	4.9	.0	.0
Indianapolis	822	194	230	29.06	29.92	−.05	78.6	+7.0	101	28	90	59	13	68	32	66	60	59	2.98	−.6	11	6,646	sw.	35	s.	2	13	7	10	5.1	.0	.0
Terre Haute	575	96	129	29.29	29.90		80.0		104	27	92	57	13	68	32	69	65	65	2.46	−1.5	8	6,105	sw.	40	n.	24	13	15	2	4.0	.0	.0
Cincinnati	627	11	51	29.25	29.91	−.08	78.1	+6.9	101	28	90	56	13	67	31	68	63	64	3.83	+.2	9	4,515	sw.	36	w.	22	11	12	7	4.8	.0	.0
Columbus	822	216	230	29.06	29.90	−.09	77.9	+7.0	101	28	89	55	13	67	30	66	60	59	2.74	−.6	5	7,058	s.	42	nw.	22	10	18	2	4.4	.0	.0
Elkins	1,947	59	78	27.97	29.94	−.06	70.4	+3.5	90	29	82	48	14	59	36	64	62	76	4.71	−.4	13	3,938	w.	29	nw.	22	8	15	7	5.6	.0	.0
Parkersburg	637	77	84	29.30	29.96	−.04	77.2	+5.8	98	29	89	54	14	66	34	68	64	66	3.72	−.3	9	4,209	sw.	43	nw.	22	12	13	5	4.4	.0	.0
Pittsburgh	842	353	410	29.02	29.90	−.09	75.9	+5.2	96	29	86	55	14	66	29	67	62	67	4.45	+.6	10	6,331	sw.	43	nw.	22	8	16	6	5.2	.0	.0
Lower Lake Region							71.2	+4.5										63	2.31	−1.0										4.9		
Buffalo	768	243	280	29.06	29.87	−.10	67.7	+3.3	90	4	75	50	7	60	32	61	57	70	1.86	−1.0	10	9,461	sw.	37	sw.	21	12	14	4	4.6	.0	.0
Canton	448	10	61	29.37	29.84		65.8	.0	93	5	77	36	8	55	39				3.01	−.3	10	5,893	w.	28	w.	24	8	14	8	5.4	.0	.0
Ithaca	836	77	100	29.00	29.88		70.2	+4.0	98	3	81	44	8	59	35	62	57	67	4.78	+1.2	11	6,028	nw.	28	se.	3	3	13	14	6.8	.0	.0
Oswego	335	71	85	29.51	29.87	−.10	65.4	+.6	89	28	75	44	7	56	31	59	55	70	1.97	−1.3	9	6,237	w.	22	n.	7	8	14	8	5.5	.0	.0
Rochester	523	86	102	29.33	29.88	−.09	70.2	+4.1	96	2	80	50	7	60	31	60	54	60	2.28	−.7	8	6,202	w.	25	w.	21	15	10	5	4.4	.0	.0
Syracuse	596	65	79	29.26	29.90	−.07	70.6	+3.7	100	2	80	46	8	61	32				2.79	−1.1	12	5,191	s.	21	s.	9	7	12	11	6.1	.0	.0
Erie	714	130	166	29.14	29.88	−.10	71.8	+5.6	97	2	81	54	7	63	32	64	60	67	1.45	−1.9	7	8,064	w.	34	se.	18	17	11	2	3.6	.0	.0
Cleveland	762	267	337	29.08	29.88	−.10	73.6	+6.5	100	28	82	54	8	65	30	64	58	60	2.26	−.9	6	8,346	n.	32	s.	21	12	16	2	4.0	.0	.0
Sandusky	629	5	67	29.23	29.90	−.08	75.0	+6.2	104	28	86	56	7	64	37				1.48	−2.0	4	5,921	sw.	23	nw.	12	8	16	6	5.0	.0	.0
Toledo	628	79	87	29.22	29.89	−.08	74.8	+6.1	101	28	86	51	7	64	37	64	58	60	1.83	−1.5	6	6,353	sw.	24	nw.	19	16	13	1	3.2	.0	.0
Fort Wayne	857	69	84	28.99	29.89		76.6	+8.1	102	28	89	52	14	64	35	64	57	56	2.67	−.9	6	6,129	nw.	35	w.	26	9	16	5	4.5	.0	.0
Detroit	626	5	78	29.22	29.88	−.09	73.2	+5.8	104	28	86	51	7	60	41	62	56	57	1.39	−2.2	8	6,782	ne.	33	nw.	26	8	18	4	5.2	.0	.0
Upper Lake Region							65.6	+3.2										68	2.59	−0.8										5.5		
Alpena	609	13	89	29.23	29.90	−.06	62.6	+2.2	98	1	72	41	7	53	51	57	53	72	3.03	−.3	10	7,171	nw.	30	nw.	30	11	14	5	4.7	.0	.0
Escanaba	612	54	60	29.23	29.89	−.05	62.6	+1.9	92	28	72	40	7	54	35	56	52	72	1.91	−1.3	10	7,037	s.	35	w.	23	9	11	10	5.4	.0	.0
Grand Rapids	707	70	244	29.12	29.87	−.10	73.2	+5.4	102	1	85	52	13	62	39	63	57	59	3.04	−.4	9	7,360	sw.	41	s.	24	9	16	5	4.7	.0	.0
Lansing	878	6	88	28.96	29.87		71.0	+4.6	97	28	84	48	14	58	38	63	59	67	1.67	−1.8	7	6,053	w.	28	w.	21	11	16	3	4.7	.0	.0
Ludington	637	5	54	29.19	29.88		64.8	+4.3	87	3	75	47	6	55	29	58			2.70	−.2	10		s.				9	12	9		.0	.0
Marquette	734	77	111	29.09	29.89	−.05	59.6	+.7	95	23	70	36	3	49	55	53	49	72	2.16	−1.1	14	6,317	nw.	31	sw.	28	5	12	13	6.7	.0	.0
Sault Sainte Marie	614	11	52	29.21	29.90	−.06	59.2	+.6	89	4	71	35	7	48	42	53	49	71	1.74	−1.2	12	5,125	se.	21	nw.	24	7	12	11	6.0	.0	.0
Chicago	673	7	131	29.18	29.90	−.06	71.6	+4.3	102	1	82	49	7	61	33	61	56	65	2.24	−1.1	16	7,008	ne.	39	nw	20	9	14	7	5.1	.0	.0
Green Bay	617	109	141	29.22	29.87	−.08	69.2	+4.3	101	1	80	47	7	59	37	60	55	64	4.47	+.8	13	7,751	sw.	37	w.	23	5	13	12	6.4	.0	.0
Milwaukee	681	97	221	29.16	29.89	−.06	68.3	+4.4	104	1	79	45	7	58	45	59	53	62	2.32	−1.1	10	8,788	n.	51	w.	20	8	15	7	5.5	.0	.0
Duluth	1,133	5	47	28.67	29.87	−.05	59.4	+2.2	85	29	70	34	7	49	41	53	50	77	3.26	−.6	15	8,648	ne.	32	nw.	5	6	12	12	5.9	.0	.0
North Dakota							64.5	+1.4										62	3.23	−.04										5.4		
Moorhead, Minn.	940	50	58	28.85	29.84	−.06	66.2	+1.8	89	29	77	42	7	55	33	58	52	62	3.93	−.1	14	6,543	nw.	38	nw.	19	8	10	12	5.8	.0	.0
Bismarck	1,674	8	57	28.10	29.85	−.02	66.0	+2.3	90	1	78	48	7	54	42	56	49	60	3.39	.0	12	7,342	nw.	27	nw.	10	10	10	10	5.4	.0	.0
Devils Lake	1,478	11	44	28.32	29.87	−.01	63.0	+1.1	88	1	74	43	12	52	39	55	48	65	3.59	.0	18	7,199	nw.	25	ne.	6	10	8	12	5.7	.0	.0
Grand Forks	833	12	67				64.6		90	29	77	41	7	52	36	57			3.70		16		nw.	31	e.	7	2	23	5		.0	.0
Williston	1,878	41	48	27.91	29.85	−.01	62.9	+.2	88	1	74	41	3	52	41	54	46	50	2.02	−1.4	11	7,158	e.	34	w.	27	12	11	7	4.7	.0	.0
Upper Mississippi Valley							78.1	+7.6										58	2.94	−1.2										4.5		
Minneapolis	918	102	208	28.89	29.85		73.0	+5.5	104	27	84	51	6	62	34	61	53	55	2.30	−1.9	12	7,861	se.	35	se.	7	7	11	12	5.7	.0	.0
La Crosse	714	11	48	29.09	29.84	−.09	74.1	+5.8	97	27	86	50	13	62	32	63	58	63	3.56	−.5	9	3,594	s.	19	w.	20	10	13	7	5.0	.0	.0
Madison	974	70	78	28.85	29.86	−.08	73.1	+5.9	100	1	84	49	7	62	37	63	58	64	2.77	−1.0	10	6,039	nw.	30	nw.	23	10	15	5	4.7	.0	.0
Charles City	1,015	10	51	28.81	29.85	−.06	75.8	+9.3	105	27	89	48	13	63	36	63	55	53	1.25	−3.4	8	5,352	se.	24	sw.	25	16	12	2	3.4	.0	.0
Davenport	606	66	161	29.22	29.87	−.07	79.4	+8.9	104	1	92	55	7	67	33	66	59	54	4.56	+.4	14	6,531	sw.	32	nw.	23	10	15	5	4.9	.0	.0
Des Moines	861	5	99	28.96	29.84	−.08	79.6	+9.0	103	26	92	56	12	67	36	65	57	53	3.18	−1.6	11	7,015	s.	38	w.	8	13	9	8	4.5	.0	.0
Dubuque	700	60	79	29.12	29.85	−.08	77.3	+7.9	104	28	89	54	13	65	34	64	57	55	3.10	−1.2	12	4,721	s.	28	nw.	23	13	9	8	4.7	.0	.0
Keokuk	614	64	78	29.23	29.89	−.06	80.4	+8.9	104	29	93	58	7	70	35	68	62	58	3.01	−1.1	8	5,262	s.	31	w.	20	13	10	7	4.2	.0	.0
Cairo	358	87	93	29.54	29.91	−.05	80.4	+4.1	99	27	90	62	13	70	26	70	66	66	.92	−2.9	10	4,944	sw.	31	nw.	9	10	11	9	5.2	.0	.0
Peoria	609	11	45	29.24	29.89	−.06	80.4	+8.3	105	1	93	53	12	66	40	67	62	61	2.82	−1.0	15	4,341	sw.	20	sw.	3	13	16	3	3.7	.0	.0
Springfield, Ill.	636	5	191	29.21	29.87	−.08	81.4	+9.2	104	27	94	59	7	69	37	68	62	56	4.55	+.5	10	7,190	s.	32	s.	3	11	16	1	4.5	.0	.0
St. Louis	568	265	303	29.29	29.88	−.07	82.6	+7.8	102	28	93	65	13	72	27	69	64	58	3.25	−.6	7	7,477	sw.	37	sw.	25	13	15		3.7	.0	.0
Missouri Valley							78.4	+7.2										54	3.33	−1.1										3.5		
Columbia, Mo.	784	6	84	29.07	29.88	−.07	80.4	+7.6	101	27	92	57	13	69	31				3.56	−1.2	10	4,791	s.	34	nw.	9	17	13	0	3.2	.0	.0
Kansas City	750	32	45	29.07	29.84	−.08	83.2	+9.6	108	23	95	60	12	72	32	68	61	52	1.71	−3.3	8	7,053	sw.	41	nw.	22	17	8	5	3.6	.0	.0
St. Joseph	967	11	49	28.84	29.83		81.6		103	29	93	57	12	70	31	68	60	54	3.96	−1.0	10	5,713	sw.	29	nw.	22	19	10	1	3.0	.0	.0
Springfield, Mo.	1,324	98	104	28.53	29.90	−.05	79.4	+6.9	98	23	90	62	17	69	30	68	63	62	2.65	−2.0	9	6,176	s.	35	nw.	17	25	5	0	1.6	.0	.0
Iola	984	11	50	28.85	29.86	−.07	80.4	+6.3	100	29	93	57	19	68	33				5.11	−.4	8		s.				19	8	3		.0	.0
Topeka	987	65	87				82.4	+9.0	105	29	95	60	10	70	34				3.00	−1.6	10	6,859	s.	32	nw.	22	15	14	1	3.2	.0	.0
Lincoln	1,189	11	81	28.59	29.82	−.08	79.8	+8.4	104	27	93	53	12	67	36	65	57	52	2.47	−1.8	10	7,225	s.	35	nw.	14	13	14	3	4.1	.0	.0
Omaha	1,105	170	200	28.69	29.84	−.07	79.0	+7.4	104	26	91	58	10	67	31	65	57	53	2.97	−1.6	12	7,719	s.	39	s.	8	15	10	5	3.9	.0	.0
Valentine	2,598	47	54	27.20	29.85	−.01	71.2	+4.3	101	26	85	49	1	58	41	59	51	53	2.37	−.5	12	6,980	n.	35	se.	13	15	8	7	4.3	.0	.0
Sioux City	1,138	64	106	28.64	29.82	−.08	76.0	+6.5	104	27	87	55	12	64	34	64	57	56	6.27	+2.3	9	6,712	nw.	37	nw.	6	11	15	4	4.8	.0	.0
Huron	1,306	60	74	28.47	29.83	−.05	72.5	+6.3	96	26	85	50	10	60	39	60	51	53	2.52	−1.3	11	7,563	se.	44	nw.	19	17	9	4	3.4	.0	.0
Northern Slope							63.4	+2.0										54	2.26	0.0										4.8		
Billings	3,140	4																														
Havre	2,505	11	67	27.29	29.89	+.04	62.3	+.3	86	11	75	41	3	50	36	52	43	56	3.12	+.3	13	7,110	e.	36	sw.	27	10	15	5	5.0	.0	.0
Helena	4,124	85	111	25.75	29.88	−.00	59.4	+.2	86	11	71	37	1	48	33	49	41	58	2.85	+.5	10	6,169	nw.	35	sw.	26	6	12	12	5.9	.0	.0
Kalispell	2,973	48	56	26.88	29.89	−.00	59.2	+1.5	89	11	71	40	5	47	36	49	40	57	2.96	+.9	10	5,055	w.	24	sw.	22	6	15	9	5.6	.0	.0
Miles City	2,371	48	55	27.37	29.87	+.02	68.3	+2.3	97	26	81	43	9	56	42	54	42	46	.66	−2.0	5	5,589	e.	41	nw.	1	12	13	5	4.4	.0	.0
Rapid City	3,259	50	58	26.54	29.88	+.03	66.6	+2.4	97	26	78	44	9	55	40	56	49	58	3.45	+.1	12	5,764	n.	33	w.	18	12	10	8	4.9	.0	.0
Cheyenne	6,094	50	71	24.00	29.88	−.02	63.6	+3.2	90	28	78	40	9	49	35	48	38	48	.87	−.7	8	6,864	se.	32	w.	19	12	14	4	4.7	.0	.0
Lander	5,372	60	68	24.60	29.83	−.02	62.8	+2.3	90	30	77	34	2	48	42	49	36	45	.90	−.2	4	4,692	sw.	27	sw.	1	13	13	4	3.8	.0	.0
Sheridan	3,790	10	47	26.02	29.85		64.2		93	26	79	36	9	50	44	53	45	56	1.38	−.7	13	4,078	nw.	24	nw.	1	15	9	6	4.2	.0	.0
Yellowstone Park	6,241	11	48		29.90	+.04	53.8	−2.2	80	30	67	30	9	41	37			59	3.48	+1.6	12	5,839	sw.	40	sw.	18	7	13	10		1.4	.0
North Platte	2,821	11	51	26.95	29.80	−.06	75.2	+7.7	101	28	89	50	10	62	39	61	53	55	2.98	−.2	11	6,196	s.	28	sw.	13	14	9	7	4.4	.0	.0

TABLE 1.—*Climatological data for Weather Bureau stations, June 1934*—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air												Precipitation			Wind										
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with 0.01 or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	Ins.
Middle Slope							78.3	+6.4										46	1.63	−1.5										3.6		
Denver	5,292	106	113	24.68	29.80	−0.04	70.0	+3.7	95	26	84	45	9	56	36	52	37	38	.22	−1.2	7	6,033	s.	29	se.	5	13	15	2	4.1	0.0	0.0
Pueblo	4,685	80	86	25.22	29.78	−.05	73.4	+4.4	98	28	89	44	8	58	45	53	35	33	.14	−1.2	2	5,752	e.	32	s.	5	16	11	3	3.8	.0	.0
Concordia	1,392	50	58	28.41	29.83	−.07	80.8	+7.8	102	29	93	56	12	69	33	66	59	52	3.34	−1.1	10	6,352	s.	35	nw.	17	13	14	3	4.3	.0	.0
Dodge City	2,509	10	86	27.30	29.82	−.05	80.0	+7.5	106	23	93	56	18	67	35	64	55	49	2.34	−1.0	8	10,475	s.	43	s.	8	21	7	2	2.6	.0	.0
Wichita	1,358	85	93	28.44	29.82	−.09	82.2	+7.8	101	20	94	62	18	71	29	67	58	49	1.78	−2.6	8	8,871	sw.	41	sw.	8	17	9	4	3.5	.0	.0
Oklahoma City	1,214	10	47	28.61	29.85	−.06	83.2	+7.2	102	20	95	64	11	71	30	68	62	55	1.98	−1.7	6	7,447	s.	34	s.	13	20	7	3	3.0	.0	.0
Southern Slope							82.7	+4.8										45	0.87	−1.6										2.5		
Abilene	1,738	10	52	28.07	29.81	−.07	85.8	+6.6	106	20	98	66	3	74	34	68	58	46	.46	−2.5	5	8,027	s.	29	n.	16	23	5	2	2.3	.0	.0
Amarillo	3,676	10	49	26.20	29.81	−.04	79.6	+6.8	103	22	93	56	4	66	34	61	51	46	1.94	−.9	10	7,685	s.	34	sw.	12	18	10	2	2.9	.0	.0
Big Spring	2,537	5	62	27.27	29.80		83.8		106	20	97	62	2	71	33	65	55	46	2.20		4		s.				23	4	3	2.6	.0	.0
Del Rio	944	64	71	28.82	29.78	−.07	85.8	+2.4	104	20	96	70	2	76	25	70	61	51	.28	−2.3	3	8,733	se.	30	se.	27	20	8	2	2.8	.0	.0
Roswell	3,566	75	85	26.26	29.75	−.05	79.7	+3.4	102	11	95	56	1	64	39	60	45	37	.80	−.9	2	6,275	se.	32	sw.	1	22	7	1	1.9	.0	.0
Southern Plateau							73.4	−0.8										30	0.19	−0.2										2.0		
El Paso	3,778	152	175	26.08	29.73	−.02	83.1	+3.5	104	12	96	63	7	70	33	57	36	23	.01	−.6	1	6,773	w.	44	sw.	1	23	6	1	1.6	.0	.0
Albuquerque	4,972	5	39	24.99	29.72		72.0		96	12	89	46	8	55	43	51	32	30	.37		4	6,974	se.	37	s.	6	18	9	3	3.1	.0	.0
Santa Fe	7,013	38	53	23.27	29.75	−.06	66.8	+2.0	88	11	80	43	4	53	36	48	30	29	.54	−.5	6	5,053	sw.	22	s.	6	21	5	4	2.9	.0	.0
Flagstaff	6,907	10	59	23.34	29.80	+.02	55.8	−3.5	88	30	74	26	7	37	47	41		39	.20		4	6,653	sw.	30	sw.	18	17	11	2		.0	.0
Phoenix	1,108	10	107	28.62	29.74	.00	83.8	−.7	110	30	99	57	7	69	43	58	34	21	.03	.0	1	4,891	w.	28	ne.	30	25	4	1	1.6	.0	.0
Yuma	141	9	54	29.60	29.74	.00	81.2	−3.5	107	11	98	57	7	65	43	62	47	36	T	.0	0	4,337	w.	24	se.	22	27	1	2	.9	.0	.0
Independence	3,957	5	26	25.88	29.85	+.07	69.4	−2.9	101	30	85	40	26	54	42	50			T	−.1	0		s.				16	6	8		.0	.0
Middle Plateau							65.4	+0.3										36	0.58	+0.1										3.6		
Reno	4,532	74	81	25.42	29.86	.00	62.5	+1.5	95	30	77	38	3	48	41	49	38	50	.62	+.3	9	5,208	w.	31	w.	25	17	7	6	3.8	.0	.0
Tonopah	6,090	12	20				61.7		89	30	74	36	6	50	32	46	31	39	.08		2		se.									
Winnemucca	4,344	18	56	25.54	29.87	−.01	62.4	−.4	95	30	79	31	4	45	44	47	33	44	.99	+.3	9	5,653	sw.	25	nw.	13	15	10	5	3.7	.0	.0
Modena	5,473	10	46	24.54	29.78	−.04	61.9	−1.4	93	30	79	32	2	45	47	43	23	28	.40	+.1	2	7,995	sw.	39	sw.	18	16	8	6	3.6	.0	.0
Salt Lake City	4,360	86	210	25.52	29.80	−.05	68.4	+1.0	93	12	81	47	2	56	34	51	34	33	.82	.0	6	6,012	nw.	32	se.	5	17	6	7	3.8	.0	.0
Grand Junction	4,602	60	68	25.28	29.78	−.05	72.0	+.6	97	30	87	43	7	57	41	50	28	24	.09	−.3	3	5,652	se.	31	sw.	18	19	10	1	2.9	.0	.0
Northern Plateau							65.3	+1.6										46	1.13	+0.1										4.5		
Baker	3,471	48	53	26.40	29.94	−.01	59.3	+.7	88	11	72	39	2	46	44	48	39	55	2.76	+1.4	9	4,723	n.	21	sw.	2	12	10	8	4.7	.0	.0
Boise	2,739	79	87	27.07	29.88	−.03	65.6	+.3	91	11	79	41	4	52	41	51	39	48	1.22	+.3	7	4,167	nw.	16	nw.	2	12	7	11	4.9	.0	.0
Pocatello	4,477	60	68	25.40	29.84	−.03	63.4	+1.2	91	30	77	37	2	49	41	47	32	40	.80	−.3	9	6,085	se.	39	s.	12	14	9	7	4.3	.0	.0
Spokane	1,929	101	110	27.87	29.88	−.06	65.4	+2.6	94	11	77	46	23	54	35	52	39	46	.84	−.4	5	5,320	se.	24	se.	25	7	16	7	5.0	.0	.0
Walla Walla	991	57	65	28.85	29.90	−.06	68.6	+2.1	100	11	80	48	2	57	36	54	42	44	1.08	.0	7	4,668	s.	24	w.	17	13	10	7	4.7	.0	.0
Yakima	1,076	58	67	28.78	29.92		69.4	+3.0	101	10	82	48	2	56	40	54	41	41	.06	−.5	3	5,967	nw.	23	nw.	26	18	5	7	3.6	.0	.0
North Pacific Coast Region							59.8	+1.4										71	0.83	−0.9										5.2		
North Head	211	11	56	29.84	30.07	+.08	55.2	+.4	64	29	58	48	1	52	11	52	51	87	.70	−1.6	10	10,497	n.	35	n.	30	8	12	10	5.9	.0	.0
Seattle	125	90	321	29.89	30.02	+.02	62.2	+3.2	82	10	71	50	2	53	27	54	47	62	.23	−1.1	4	6,193	n.	40	sw.	21	11	13	6	4.7	.0	.0
Tatoosh Island	86	10	54	29.97	30.07	+.05	53.7	+.7	61	9	57	46	1	50	12	51	50	90	.82	−2.4	10	6,499	sw.	31	sw.	21	4	13	13	6.4	.0	.0
Medford	1,329	29	58	28.56	29.94		64.7		100	30	80	38	3	50	47	53	44	58	.83	+.1	8	4,909	nw.	27	nw.	23	12	10	8	4.5	.0	.0
Portland, Oreg.	153	68	106	29.86	30.02	−.02	64.0	+1.6	88	11	74	47	1	54	30	56	49	63	.96	−.6	8	4,748	nw.	18	sw.	1	10	7	13	5.5	.0	.0
Roseburg	510	45	76	29.47	30.01	−.02	63.6	+1.1	93	10	77	40	2	50	40	55	48	65	1.43	+.3	5	3,935	n.	20	sw.	25	10	11	9	4.5	.0	.0
Middle Pacific Coast Region							66.0	+1.8										65	0.40	0.0										3.1		
Eureka	62	73	89	29.96	30.03	−.02	55.6	+1.3	66	27	60	47	3	51	14	52	50	84	.29	−.4	3	5,658	n.	26	n.	22	13	7	10	4.7	.0	.0
Red Bluff	330	5	58	29.49	29.84	−.04	76.1	+1.3	113	30	90	52	1	62	40	59	47	44	.34	−.1	4	5,019	nw.	22	se.	10	23	3	4	2.8	.0	.0
Sacramento	66	87	115	29.78	29.84	−.05	71.4	+2.0	112	30	86	50	3	56	44	58	50	56	.30	+.2	3	6,168	s.	21	sw.	24	24	3	3	1.8	.0	.0
San Francisco	155	208	243	29.74	29.91	−.05	61.0	+2.5	95	29	68	50	2	54	34	54	51	75	.68	+.5	3	5,470	sw.	25	w.	24	19	4	7	3.1	.0	.0
South Pacific Coast Region							67.5	−1.2										66	0.31	+0.2										4.6		
Fresno	327	97	105	29.50	29.85	.00	73.2	−2.6	106	30	87	50	1	59	38	58	46	46	.05	.0	1	5,477	nw.	21	nw.	23	24	2	4	2.1	0	.0
Los Angeles	338	159	191	29.56	29.92	+.02	65.2	−1.2	81	28	72	54	6	58	22	58	54	72	.41	+.3	1	4,199	sw.	19	nw.	30	8	11	11	5.4	.0	.0
San Diego	87	62	70	29.83	29.92	.00	64.0	+.1	71	30	68	56	6	60	12	59	56	79	47	+.4	5	5,361	w.	21	s.	5	5	13	12	6.2	0	.0
West Indies																																
San Juan, P.R.	82	9	54	29.94	30.02		79.7	.0	90	16	85	72	10	74	15				4.99	−.3	12	8,819	e.	27	ne.	27	6	20	4	5.3	.0	.0
Panama Canal																																
Balboa Heights	118	6	97		[1]29.84	+.01	80.2	+.1	92	29	86	72	6	74	18			[1]88	10.85	+2.6	19	3,474	nw.	19	se.	5	0	13	17	7.5	.0	.0
Cristobal	36	6	97		[1]29.84	.00	82.2	+1.8	91	13	88	74	28	77	15	77	75	[1]82	9.89	−3.8	18	5,046	se.	23	sw.	19	0	9	21	7.9	.0	.0
Alaska																																
Fairbanks	454	11	87	[2]29.32	[2]29.82		57.9		84	29	71	34	1	45	36	48	38	56	.30		4	4,754	sw.	25	sw.	21	7	16	7	5.5	.0	.0
Juneau	80	96	116	[2]29.89	[2]29.98		52.6		75	5	59	40	13	46	28	48	43	75	3.91		15	4,660	s.	27	se.	10	3	4	23	7.9	.0	.0
Hawaiian Islands																																
Honolulu	38	86	100	[2]30.00	[2]30.04		77.4	+.8	85	9	82	70	3	73	12	70	67	71	1.84	+.9	18	7,567	e.	27	e.	19	14	12	4	4.4	.0	.0

[1] Observations taken bihourly.

[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, June 1934*

Data not received in time for inclusion in this issue of the REVIEW; the June figures will be printed in the July issue.

SEVERE LOCAL STORMS, JUNE 1934

(Compiled by Mary O. Souder)

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Malad, Idaho	1	11:45 am.	[1] 2			Hail	Leaves of vegetation punctured; no estimate available of property destroyed, probably light; path 3½ miles long.	Official, U.S. Weather Bureau.
Jacksonville, Fla	1	1:51-8:40 p.m.				Thunderstorm, heavy rain and hail.	Considerable damage to streets and gardens.	Do.
Leesburg (near), S.C	1	3:30 p.m.	3,080		$10,000	Hail	Loss to crops	Do.
Garfield and Roseburg Counties, Mont.	1	4-5 p.m.	2,640	1	5,000	Wind and hail	$5,000 property damage in southern county alone; sheep herder killed near Grisdella when the sheep wagon in which he sought shelter was demolished; winter wheat crop wiped out and loss in spring wheat; path 10 miles long.	Do.
Troy, S.C	1	5 p.m.	do		6,000	Hail	Loss to crops; damage to buildings	Do.
Sunray, Tex	1	5:30 p.m.	do		1,500	Wind	Damage to buildings	Do.
Pana, Ill., and vicinity	1		880		2,500	Hail	Loss to crops; property damaged; path 3 miles long.	Do.
Philadelphia (near), Miss	1	P.m.		1		Electrical and rain	Woman killed taking clothes from wire line	Do.
North St. Louis, Mo	1	do			200,000	Electrical and wind.	Several buildings damaged, trees, wires, and poles blown down; lightning caused fire in warehouse where several bales of cotton were stored.	Do.
Butte, Mont	1	P. m				Snow	Snow after several hours of heavy rain; motorists and pedestrians unprepared; traffic seriously hampered.	Do.
Chester (near), S.C	1	do	[1] 1		3,000	Hail	Crop damage	Do.
Gering and Scottsbluff, Nebr	2	8-11 p.m.	1,333		32,000	Hail, wind, and rain.	About 8 square miles of crops destroyed by hail; irrigation ditches damaged by flooding; electric transmission lines blown down.	Do.
Nettleton, Miss	2				1,500	Electrical	No details	Do.
West Point, Miss	2				8,000	Thundersquall	Storm attended by high wind and heavy hail, resulting in damage to mercantile establishments.	Do.
Springfield, Mo	2					Wind, rain, and hail.	Trees and telephone wires damaged; streets flooded in northeastern portion of the city.	Do.
Stillwater County, Mont	2-5				100,000	Hail	Severe loss to crops; sheep killed; storm of 5th most extensive, and damaging path varied from 1½ to 3 miles; storm of 2d covered only narrow strip through extreme south end of the county.	Do.
Marathon, Tex	3	11:45 p.m.		1		do	Sheep and goats killed; damage to roofs, houses, and outbuildings.	Do.
St. Louis and St. Louis County, Mo.	3	P.m		2		Electrical and hail	Trees damaged; 2 boys killed by lightning	Do.
Lee County, S.C	3	do			1,000	Hail	Damage to crops; path narrow	Do.
Electric Mills, Miss	3				20,000	Electrical	No details	Do.
Cortland, N.Y	3					Thundersquall and hail.	Hail caused considerable damage to windows, roofs, and automobile tops; high winds damaged telephone and power lines.	Do.
Killawog, N.Y	3				1,000	Severe thunderstorm.	Flood waters washed 900 feet of track of the Lackawanna R.R.; sawmill and piles of lumber carried away.	Do.
Norwich, N.Y	3				30,000	Electrical	Lightning caused fire in Elliott lumber mill	Do.
Acton, Mont., 9 miles east	3			1		Heavy rain, electrical.	Man and horse killed during severe electrical storm.	Do.
Fort Laramie (near), and Jay Em, Wyo.	3					Heavy rain and hail.	All crops washed out	Do.
Maple Plain, Minn., and vicinity.	4	1:30 p.m.			5,000	Thundersquall	Several barns and sheds blown over, others moved from their foundations or damaged; branches of trees blown off and trees uprooted.	Do.
Dexter, Minn	4	2:15 p.m.	13		1,200	Tornado	Barn and silo demolished; path 110 yards long	Do.
St. Louis and St. Louis County, Mo.	4	P.m.		1		Thundersquall and hail.	Trees uprooted and wires blown down; boy killed by lightning at Pine Lawn.	Do.
Aledo (near), Ill	4				4,000	Wind	No details	Do.
Sumner, Richfield, Postville, Elkport, and Hawkeye, Iowa.	4				1,500	Rain, electrical, and wind.	Barn and 25 tons of hay, corn crib and windmill destroyed by lightning and 8 cattle killed; another barn moved 8 inches from its foundation, silo blown down and machine shed demolished; in Elkport, barn and cattle shed struck by lightning and burned; in Hawkeye several windmills destroyed, dwelling moved from its foundation and buildings damaged; loss in Elkhorn, only estimate given.	Do.
Marquette, Mich	4					Thunderstorm	Farmhouse struck by lightning and several persons stunned.	Do.
Valmora, N.Mex	5	1 p.m.	[1] 6			Hail	Considerable damage to gardens	Do.
Alpena, Mich	5	4 p.m.		1		Electrical	Telephone pole and tree struck; man killed and a woman injured by lightning.	Do.
Clovis, N.Mex	5	5 p.m.	[1] 7			Hail	30 to 50 percent of growing wheat damaged	Do.
Chicago, Ill., and vicinity	5	P.m				Hail, wind and heavy rain.	Trees and high-tension wires blown down; basements flooded.	Do.
Downing, Mo., 7 miles north	6	4 p.m.			3,000	Heavy hail	Damage to property, orchards, crops, and trees	Do.
Marathon, Tex., north of	6					Hail	1,000 sheep and 23 cattle killed	Do.
McKinley, Wyo	6				1,500	Heavy rain and hail.	2 storms caused losses in beets, grains, and alfalfa	Do.
Wishek (near), N. Dak	6-7					Tornado	4 C.C.C. workers hurt and several buildings damaged.	Do.
Iowa, Big Sioux Watershed	6-8			1		Heavy rainfall and wind.	High water and flood; bridges and culverts in all sections of Sioux City threatened; damage to crops and tangible property; man killed by live wire which had blown down	Do.
Orchard, Nebr	7	11:20 a.m.	833		2,000	Tornado	Barn wrecked; livestock killed	Do.
Norton-Almena, Kans., and vicinity.	7	6 p.m.	[1] 2		50,000	Heavy hail	Damage to crops, path 15 miles long	Do.
Montezuma-Cimarron, Kans	7	6:30 p.m.	[1] 7		100,000	Heavy hail and rain.	Chief damage from hail; wheat beaten into ground; path 20 miles long.	Do.
Chippewa, Lac Qui Parle, Yellow Medicine, Lyon, Redwood, and Renville Counties, Minn.	7	6:30-12 p.m.			2,000	Wind	Small damage reported	Do.
Redwood Falls, near, Minn	7	8 p.m.			10,000	Tornadic wind	Damage to buildings at fair grounds	Do.

[1] Miles instead of yards.

SEVERE LOCAL STORMS, JUNE 1934—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Liberal, Kans	7	P.m.			$3,000	Wind and hail	Damage mostly at airport	Official, U.S. Weather Bureau.
Avon, S.Dak., 16 miles northeast.	7	do		1		Tornado	Outbuildings on farm demolished, residence only left standing; man and livestock killed when barn blew over; 3 injured, 1 seriously; buildings on another farm damaged considerably.	Do.
Brookings, Moody, Minnehaha, and Union Counties, S.Dak.	7-8				39,000	Heavy rain	High water and flood damage to crops and tangible property.	Do.
Big Sioux River, Perry Creek, and Floyd River, Iowa.	7-9				521,500	Heavy rain and flood.	3,000 persons homeless; 541 homes and business places flooded; bridge collapsed.	Do.
Newberry, near, S.C	8	2:30 p.m.			3,000	Electrical	Large barn and contents burned	Do.
Reeseville, Wis	8	do	220		4,000	Tornado	No details	Do.
Greensburg, Kans., and vicinity.	8	4:15 p.m.	33		3,000	Tornado	Telephone and power lines damaged; many small buildings blown over; path 20 miles long.	Do.
Lower Red Lake, south shore, Minn.	8	5 p.m.				Thunderstorm and heavy hail.	Considerable damage to gardens and fruits	Do.
Lafayette, Green, Rock, and Walworth Counties, Wis.	8	8:30-9:30 p.m.			30,000	Thundersquall	Considerable structural damage reported	Do.
Brown and Doniphan Counties, Kans.	8	P.m.				High wind and hail.	Telephone and power lines damaged; small buildings blown down, larger ones damaged; amount of loss not estimated.	Do.
Raymond, S.Dak., 3 miles northwest.	8	do			5,000	Tornadoes	Observers report 4 funnel clouds; 1 dwelling, several barns and other small buildings demolished.	Do.
Orient and Northwood, Iowa	8				7,000	Wind	Large barn wrecked; farm buildings damaged; 2 windmills blown down; an orchard ruined.	Do.
Sac County, Iowa, northeastern portion.	8		[1] 7			Tornado	2 persons injured; buildings on 10 farms demolished; trees and buildings in path destroyed.	Do.
Omaha, Nebr	8				5,000	Wind and hail	Most of damage to greenhouses; telephone and power lines, signboards and trees blown down.	Do.
Cairo, Ill	9	5:32 p.m.			1,000	Thundersquall	Lightning struck and blew up intake well of the Illinois Power & Light Corporation; city in darkness several hours; tree branches blown down breaking many wires.	Do.
Bucklin, Kans	10	2:30 a.m.				Electrical	Granary, automobile, truck, feed grinder, and other implements on a farm destroyed by fire after being struck by lightning.	Do.
Binghamton, N.Y., and vicinity.	10	11:52 a.m.-4 p.m.		1		Electrical and heavy rain.	In Taylor Center a girl, sitting by the telephone in her home, killed by lightning with no damage to the house; barn in North Pitcher and one in Merrill Creek destroyed by lightning; heavy rain caused landslide which delayed traffic.	Do.
Providence, R.I., and vicinity	10	3:33 - 4:55 p.m.				Thunderstorm, excessive rain and hail.	In Greenwood plane damaged and forced down; 1,000 telephones out of commission; in Pawtucket 2 houses were struck; many automobiles disabled because of water in distributors.	Do.
Tontitown, Ark	10	8 p.m.	[1] 4		450,000	Tornado and hail	Path 12 miles long; no details	Do.
Milford, Windham, Windsor, East Granby, Simsbury and Ellington, Conn.	10					Heavy thunderstorm.	3 buildings struck by lightning; in Windham tree fell across high tension wires delaying traffic; damage to orchards.	Do.
Atlanta, Ga	11					Electrical	Several buildings struck by lightning causing much damage.	Do.
St. Francis, Kans., and vicinity	12	3 p.m.	[1] 6		30,000	Heavy hail	Chief damage to crops which were, in some localities, completely destroyed; path 15 miles long.	Do.
Sherman and Thomas Counties, Kans.	12	3-4 p.m.	[1] 6		200,000	do	One of the most severe storms known locally; in some places hailstones piled up 4 to 5 inches; much damage to crops; path 20 miles long.	Do.
Scott City, Kans., 10 miles north.	12	5:30 p.m.			5,800	Tornado	Several small buildings destroyed and trees blown down.	Do.
Ravenna, Kans., and vicinity	12	8:30 p.m.	[1] 10			High wind	A residence and several small farm buildings blown down or badly damaged; amount of loss not estimated; path 14 miles long.	Do.
Dodge City, Kans., 20 miles northwest.	12	P.m.	[1] 6			Tornado	Barns, windmills, granaries and trees destroyed	Do.
Norton, Kans., 18 miles northwest of.	12	do	[1] 2		25,000	Heavy hail	Damage to crops; path 12 mile long	Do.
Griggsville, Ill	12					Wind	Damage to telephone and electric lines	Do.
Lehigh Valley, Pa., and adjacent areas.	12				30,000	Electrical	Many buildings destroyed by fire; greatest single loss electric power plant at Easton estimated to be $30,000.	Do.
Tampa, Davenport, St. Leo, De Land, and Glen St. Mary, Fla.	12-14				100,000	Heavy rain and flood.	Much loss to crops; rivers, ponds, and lakes overflowed causing much damage to highways, bridges, and railway fills.	Do.
Otis, Colo	14	P.m.				Rain	Rancher's family marooned over night on hilltop; ranch outbuildings swept away; 40 cattle drowned.	Do.
Yankton, S.Dak	14					Tornado and heavy rain.	Roof torn from North Western Depot and carried 200 feet; box cars blown along track and derailed; tree uprooted, wrecking sidewalks; communication and power lines down.	Do.
Buffalo, N.Y., and vicinity	15	1:45-2:15 p.m.		1	106,000	Thunderstorm and hail.	Boy killed and 2 others seriously injured when they took refuge under a tree; crops reported ruined by large hailstones over an area 1 mile wide and 6 miles long.	Do.
Wiley, Colo	15	3 p.m.	[1] 2		10,000	Hail	Standing grain ruined; some loss to poultry	Do.
McClave, Colo	15	4-5 p.m.	[1] 1		1,500	do	Some damage to grain fields	Do.
Lefors-Pampa, Tex	15	5 p.m.	[1] 4		200,000	Hail and wind	22 oil derricks blown down; buildings and houses damaged; loss to wheat crop.	Do.
Leoti, Kans., and vicinity	15	6 p.m.	880		1,500	Small tornado	Path 3 miles long; no details reported	Do.
Lamar, Colo	15	P.m.				Rain	Streets and parks flooded; highways washed out temporarily delaying motor travel.	Do.
Grayrocks-Glendon, Wyo	15				10,000	Heavy hail	Loss to crops	Do.
Hillsdale, Wyo., and vicinity	15					do	Sheep and chickens killed; crop loss; paint and shingles on buildings damaged.	Do.
Canton, Okla	16	1-1:30 a.m.	[1] 4		40,000	Hail and wind	Principal loss to wheat and cotton, cotton crop being practically ruined; path 30 miles long.	Do.
Oklahoma, southwestern and central-western portions.	16	P.m.		1		Tornadic wind, rain and hail.	4 persons injured; much damage by wind; cotton and other crops harmed by blistering sand storm and hail.	Do.
Louisiana, Marsh Island, through Iberia, St. Martin, and West Baton Rouge Parishes, through East Feliciana Parish to Mississippi.	16			3	2,605,000	Tropical storm	Amount stated to buildings alone; loss to crops, principally corn, gardens, truck and cotton, considerable but not yet known; business temporarily suspended in Baton Rouge.	Do.
Mississippi, western area	16-17			4	3,000,000	do	Numerous injuries reported; loss to crops alone indicated.	Do.
Lake Alice, N.Mex	17	P.m.				Hail	Hail covered the ground to depth of 3 inches; gardens destroyed; no replanting because of drought.	Do.

[1] Miles instead of yards.

SEVERE LOCAL STORMS, JULY 1934—Continued

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Red River Valley, Tenn	17				$250,000	Excessive rain	Estimated loss to crops $150,000; damage to roads and bridges $100,000.	Official, U.S. Weather Bureau.
Davidson and Robertson Counties, Tenn.	17–18	5 p.m.	50		3,000	Tropical storm and tornado.	Small tornado occurred on the 17th in sparsely settled area north of Joelton with damage to farm buildings.	Do.
Fort Hall, Idaho	18	1 p.m.	[1] 1			Hail	Value of property destroyed not estimated, probably slight, path 13 miles long.	Do.
Idaho Falls, Idaho, vicinity of	18	4–5 p.m.				do	Considerable damage to peas in small area; less damage to grain.	Do.
Collbran, Colo.	18	6 p.m.				Small tornado	Slight damage to buildings; considerable loss in hay.	Do.
Maryland, eastern portion	18–19				50,000	Wind and rain	Winds of gale force caused unusually high tides in Chesapeake Bay and Baltimore Harbor.	Do.
Leoti, Kans., east of	19					Tornado	2 small buildings damaged; path not well defined.	Do.
Cherry County, Nebr., 5 miles south of Valentine.	19	3:30–6 p.m.	[1] 10			Wind and hail	Hailstones as large as medium sized oranges; damage mostly to range land; loss in poultry and hay; path 40 miles long.	Do.
Leoti and Marienthal, Kans., and vicinity.	19	5:45 p.m.				Tornado	Small buildings damaged; path, not well-defined, was 15 miles long; 5 other tornado clouds reported at about the same time.	Do.
Aberdeen-Mitchell and eastward, S.Dak.	19	7–10 p.m.			50,000	Wind and dust	Several thunderstorms, moving along a wide front, were preceded by winds of gale force and caused thick dust and much property damage; lowest visibility, objects obscured at distance of 10 feet; hangar at Mitchell Airport destroyed and airplane wrecked; communication wires down; considerable structural damage and many trees broken.	Do.
Yellow Medicine, Lac Qui Parle, Chippewa, Swift, Stevens, Kandiyohi, Meeker, Stearns, and Lincoln Counties, Minn.	19	9–10 p.m.	[1] 20		898,000	Tornadoes	2 persons injured; much livestock and poultry killed; serious loss in corn crop; many trees uprooted and much property damaged. These storms originated in east-central South Dakota, and struck the Minnesota border near Canby; minor losses over a belt extending eastward from Beardsley to Taylor Falls and southward to the Iowa border; path of greatest destruction 20 miles wide and 100 miles long.	Do.
Superior, Nebr	19	9–11 p.m.	880		5,000	Wind	Small buildings, silos, and trees blown down	Do.
Ruthven, Iowa	19	P.m.			5,500	Tornado	Town pumphouse and church wrecked; roof of church carried a block; numerous chimneys wrecked; trees uprooted and windows broken.	Do.
Honey Creek, Iowa	19					Wind	Telephone lines damaged; trees blown down	Do.
Galena-Menominee, Ill.	20				3,000	do	No details	Do.
La Salle, Ill	20				2,500	Electrical	do	Do.
Wiota, 5 miles southeast to northeast of Berea, Iowa.	20			1	250,000	Tornado	Telephone poles down; barns crushed like paper boxes; trees uprooted; corn cribs and chicken houses blown down; several persons injured.	Do.
Buchanan, Platte, Nodaway, and Harrison Counties, Mo.	20	2 p.m.	[1] 1		68,000	Hail	Severe damage to crops	Do.
Brodhead, Wis.	20	5:45 p.m.	330		10,000	Tornado	Damage to farm buildings	Do.
Grasshopper, Lancaster, and Shannon, Kans.	20	6–6:30 p.m.			20,000	Heavy hail	Chief loss to crops; property damaged	Do.
Rushville, Sugar Lake, and Bean Lake, Mo.	20	6–7 p.m.				Thunderstorm and hail.	Thousands of dollars' damage; tobacco and corn over a wide area ruined; property damaged; loss in fruits and gardens.	Do.
Lafayette, Green, Rock, Walworth, Jefferson, Waukesha, and Milwaukee Counties, Wis.	20	do	[1] 38	1	400,000	Thundersquall	Many injuries reported; much property damaged; wires and poles down; barns and buildings demolished; at Milwaukee the highest wind velocity, 51 miles, was recorded; total damage in this city $200,000; at Monroe, Wis., a man was killed when a tree fell on his automobile just as he arrived at his residence.	Do.
Elmira, N.Y.	21	6:17–7 p.m.		1		Electrical	Boy killed by lightning and his companion uninjured while working in a truck garden in the school yard.	Do.
Thomas County, Kans., northwestern portion.	21	11 p.m.	[1] 10		4,000	Heavy hail	Damage to crops; path 20 miles long	Do.
Evansville, Ind.	21	P.m.			20,000	Thundersquall and hail.	Considerable damage by high wind; trees uprooted; wires down; small loss to crops and gardens.	Do.
Anderson County, Kans., southwestern portion.	21	do	[1] 2		500	Hail and wind	Small buildings destroyed; path 3 miles long	Do.
Winchester, Ill.	22				1,500	Wind	No details	Do.
Waynedale, Ind., suburb of Fort Wayne.	22				20,000	Thundersquall	1 person injured; property damaged; amount estimated for buildings alone; additional loss because of many valuable trees being damaged or destroyed.	Do.
Atwood, Kans., 15 miles southwest.	22				10,000	Heavy hail	Crops damaged	Do.
Parkersburg, W.Va.	22					Thundersquall and hail.	Excessive precipitation, streets flooded	Do.
Osborne County, Kans.	22	1–2 a.m.				Wind and rain	At Osborne high school and contents damaged to extent of $700; much property damaged.	Do.
McPherson County, Kans.	22	3 a.m.	[1] 30		12,000	Wind	Chief damage to oil derricks, telephone and power lines and trees; path 30 miles long.	Do.
Topeka, Kans.	22	A.m.				do	Wires down; 5 miles from city a 2-story barn was blown down; windows blown in.	Do.
Philadelphia, Pa., and suburbs.	22	P.m.		3	50,000	Electrical and wind.	3 roofs destroyed by lightning; an old house collapsed; church steeple damaged by lightning; other minor damage; 2 persons instantly killed, another died from shock.	Do.
Pittsburgh and Arnold, Pa.	22	do			50,000	do	Several buildings demolished by lightning; many trees uprooted in Pittsburgh; an old railroad station demolished by wind in Arnold.	Do.
Westmoreland County, Pa.	22	do			25,000	Electrical, wind, and hail.	Royal Hotel unroofed; many trees uprooted; much hail damage in Irwin.	Do.
Franklin and Hamilton Counties, Ohio.	22	do			80,000	Thundersquall, heavy rain.	Loss in Franklin County $30,000, and in Hamilton County, $50,000.	Do.
Mountain Grove, Mo., vicinity of.	23	11 a.m.	[1] 1		7,000	Heavy hail and wind.	Windows, screens, and roofs demolished	Do.

[1] Miles instead of yards.

SEVERE LOCAL STORMS, JUNE 1934—Continued

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Chisago and Washington Counties, Minn.	23	1:30 p.m.			$17,500	Thundersquall, heavy rain, and hail.	Hailstones as large as baseballs in Chisago County; $12,500 to growing crops; $5,000 loss to window panes and automobile tops.	Official, U.S. Weather Bureau.
La Crosse, Wis.	23	4 and 6 p.m.			5,000	2 hailstorms	First storm, hail heavy in southeast section of the city causing slight damage to crops; second storm, at 6 p.m., crop damage in La Crosse County estimated to be $5,000.	Do.
Winona, S.C.	23	P.m.	880		3,500	Wind	Damage to buildings; cow killed by lightning	Do.
Lake County, Ill.	23			2		Electrical	Small boat capsized and 2 persons drowned	Do.
Wisconsin, west, east-central, and southern counties.	23		[1] 100	1	1,000,000	Thundersqualls	Most damage to farm buildings, smokestacks on factories, and power and telephone lines; loss to crops in some localities; heavy damage to trees reported in Green Bay, La Crosse, Madison, and Milwaukee; man killed when pinned below rafters of barn which had blown down; 5 persons injured by flying glass.	Do.
Columbia, S.C.	24	5:30 p.m.	880		2,000	Wind	Grandstand at fair grounds unroofed	Do.
Geneseo, Ill.	24		do.		3,500	Hail, electrical	Path 1 mile long; no details	Do.
Freelandville, near, Ind.	24				60,000	Thundersquall	Church destroyed after being struck by lightning.	Do.
Hamel, Minn.	25	3:45 p.m.	100	1	10,000	Tornadic wind	Man killed when he sought refuge in a barn that was demolished, the roof being lifted and carried 60 feet; man injured when caught under falling beam of a barn that was demolished; livestock and poultry perished; property damaged; path 3 miles long.	Do.
Dakota, Mower, Dodge, Olmstead, and Winona Counties, Minn.	25	4:30 p.m.			140,000	Wind	1 person injured; damage to wire systems and property loss to crops; livestock killed.	Do.
Neilsville, Wis., vicinity of	25	5-7 p.m.	1,320		10,000	Hailstorm	Numerous window panes in residences and greenhouses broken; roofs of buildings and automobile tops punctured; 60 percent of growing crops ruined; some farmers reporting complete loss of corn crop.	Do.
Briggsville, Wis., 1 mile north	25	11:30 p.m.	880		3,000	Thundersquall	Barn wrecked and 2 windmills 1½ miles east of the barn demolished; few scattered trees uprooted.	Do.
Seward, Raymond, and Ellinwood, Kans.	25	P.m.	[1] 5		3,000	Wind	Chief damage in Ellinwood where storm had many characteristics of a tornado; warehouse and a number of small buildings badly damaged; path 25 miles long.	Do.
Minnesota, extreme southeastern counties.	25	do.				Hail and wind	Damage to growing crops, especially peas	Do.
Mount Pulaski, Dawson and Elkhart, Ill.	25		[1] 10		7,500	Hail	Heavy loss to crops; property damaged; path 12 miles long; $7,500 amount of damage in Mount Pulaski alone.	Do.
Kosciusko County, Ind.	26				7,500	Wind	No details	Do.
Clarence, Iowa	26		567		10,000	Tornado	Damage of $10,000 to property in area of 3 blocks; wires and trees blown down; box hurled through the dining room window of a home and across the house.	Do.
Cascade, Chouteau, Fergus, Hill, Judith Basin, and Teton, Phillips, Petroleum, Garfield, McCone, Richland, Dawson, and Sheridan Counties, Mont.	26		[1] 1-6		600,000	Hail, wind, and rain.	Property damage; loss to crops, especially winter wheat, poultry killed.	Do.
Summit County, Ohio	26				10,000	Wind	No details	Do.
Butte, Mont.	26	11:30 a.m. 2:30 p.m.		1	10,000	do.	Workman swept from the runway of a gasoline refinery and hurled 20 feet to his death; property damage.	Do.
Saline City-Clay City, Ind.	26	5-6 p.m.	440		2,500	Tornado	Path several miles long	Do.
Fort Wayne, Ind., southwestern portion.	26	P.m.			10,000	Thundersquall, heavy rain.	Man severely injured; very heavy toll taken of magnificent shade trees, several falling on residences causing much damage.	Do.
Williston, N.Dak.	26	do.				Wind	Telegraph wires blown down; Williston Ice & Coal Co.'s tipple, 1½ miles from city blown over; roof of 2 box cars blown off.	Do.
Union and Granger Counties, Tenn.	28	5-6:30 p.m.	[1] 1		12,000	Hail	Destruction to crops ranged from 25 percent to almost a complete loss; property damaged; path 20 to 25 miles long.	Do.
Ebenezer, S.C.	28	P.m.	880		1,000	Thunderstorm	Damage to telephone and power lines and to buildings.	Do.
Malaga, N.Mex.	29	9 p.m.	[1] 1		1,200	Hail	200 acres of cotton and 30 acres of feed destroyed	Do.
New Liberty, Iowa	29				2,500	Wind	Loss to crops; damage to farm buildings	Do.
Lucas County, Ohio	29				50,000	do.	No details	Do.
Byllesby, Va., vicinity of	30	2:30 p.m.	440		500	Wind and hail	Corn and other crops damaged by hail, fruit trees by wind.	Do.
Franklin County, Va.	30	3 p.m.	[1] 1		500	Hail	Damage to trees, flowers and gardens; path 5 miles long.	Do.
Chattanooga, Tenn.	30	5:35-7:42 p.m.				Electrical and heavy rain.	Heavy and destructive discharges of lightning	Do.
Springfield, Ill.	30				2,000	Electrical	No details	Do.

[1] Miles instead of yards.

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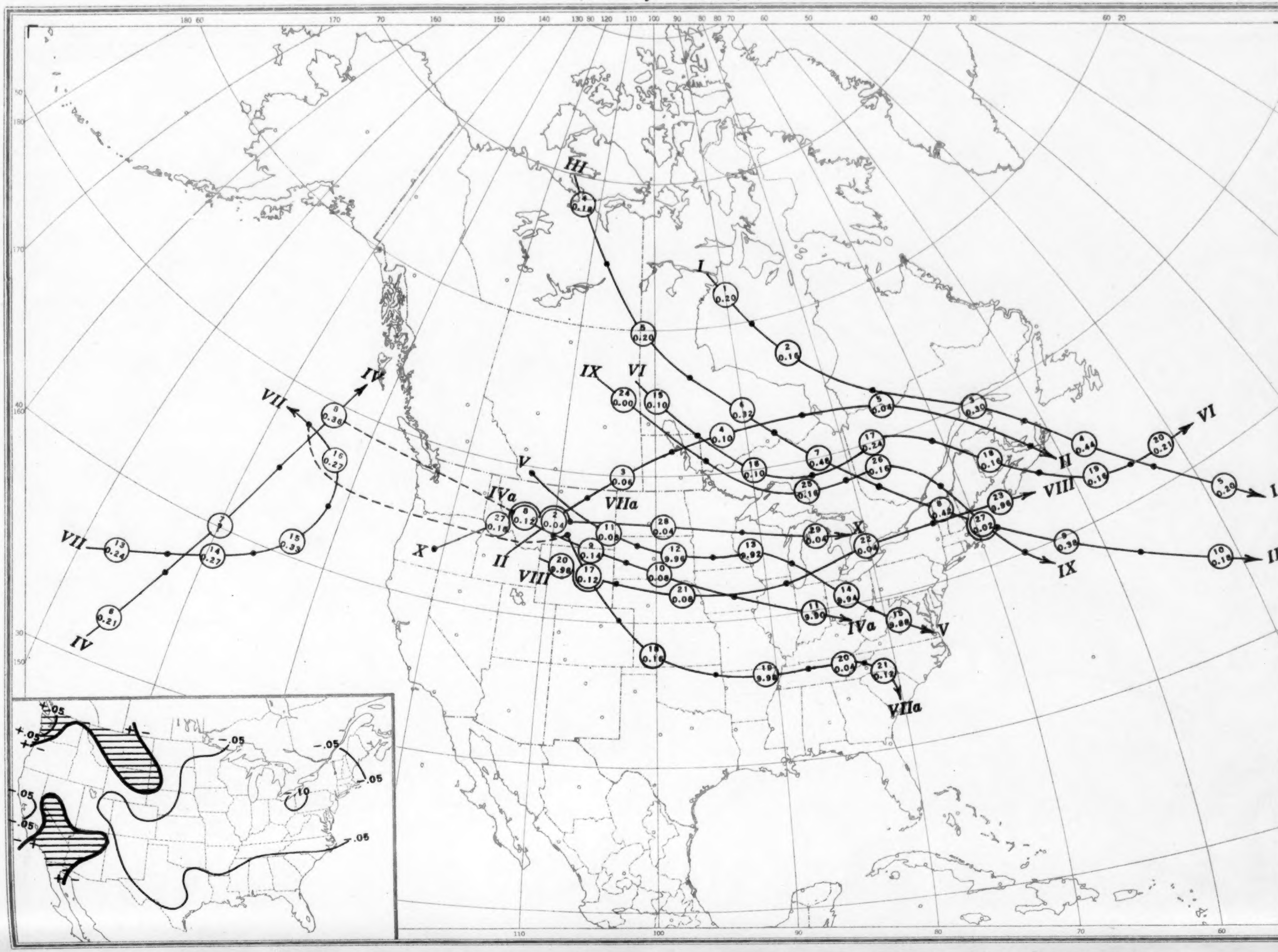
Chart I. Departure (°F.) of the Mean Temperature from the Normal, June 1934

Chart I. Departure (°F.) of the Mean Temperature from the Normal, June 1934

UNIV. OF MICH.

Chart II. Tracks of Centers of Anticyclones, June 1934. (Inset) Departure of Monthly Mean Pressure from Normal

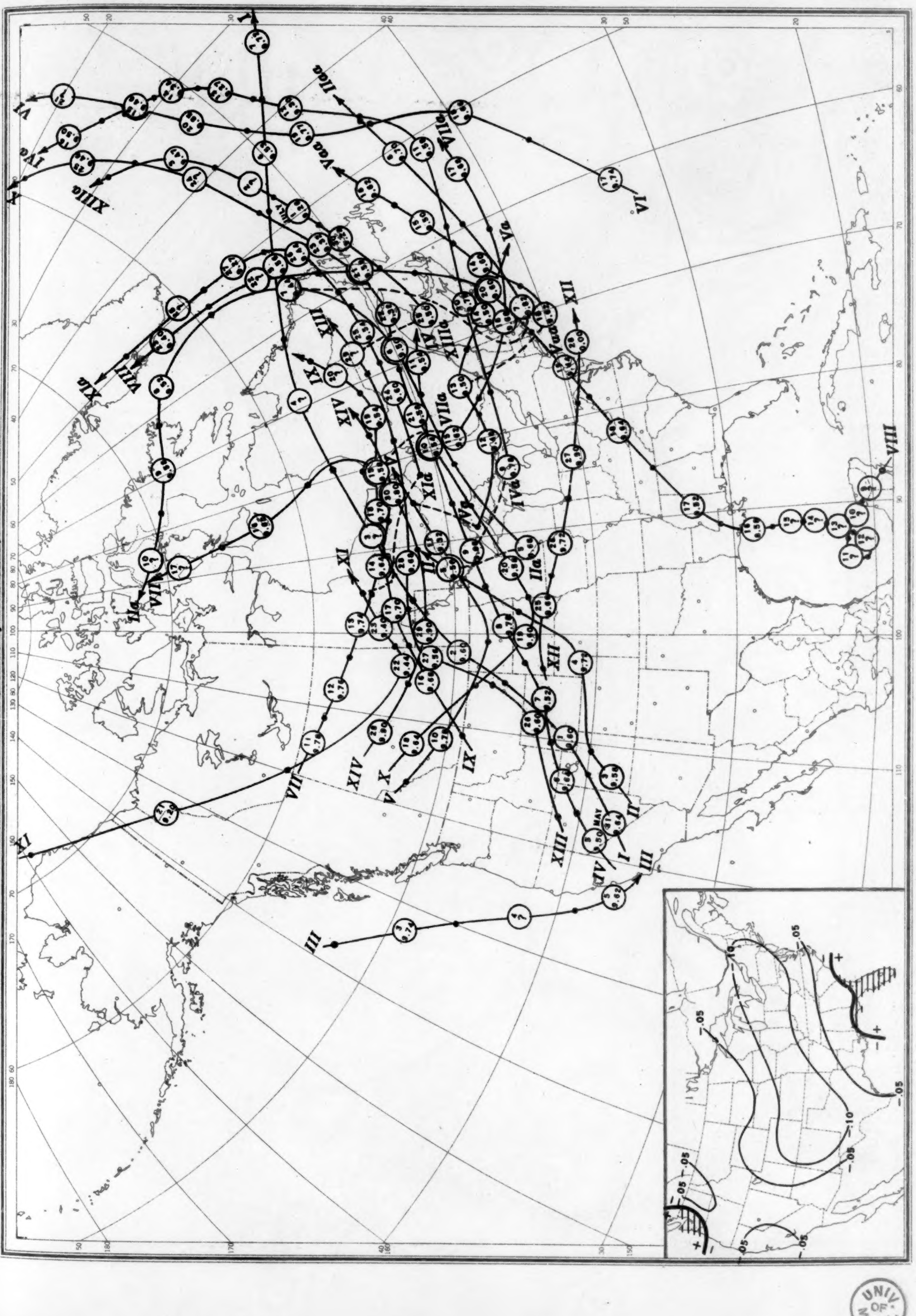
(Plotted by G. E. Dunn)



Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, June 1934. (Inset) Change in Mean Pressure from Preceding Month

Chart III. Tracks of Centers of Cyclones, June 1934. (Inset) Change in Mean Pressure from Preceding Month
(Plotted by G. E. Dunn)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, June 1934

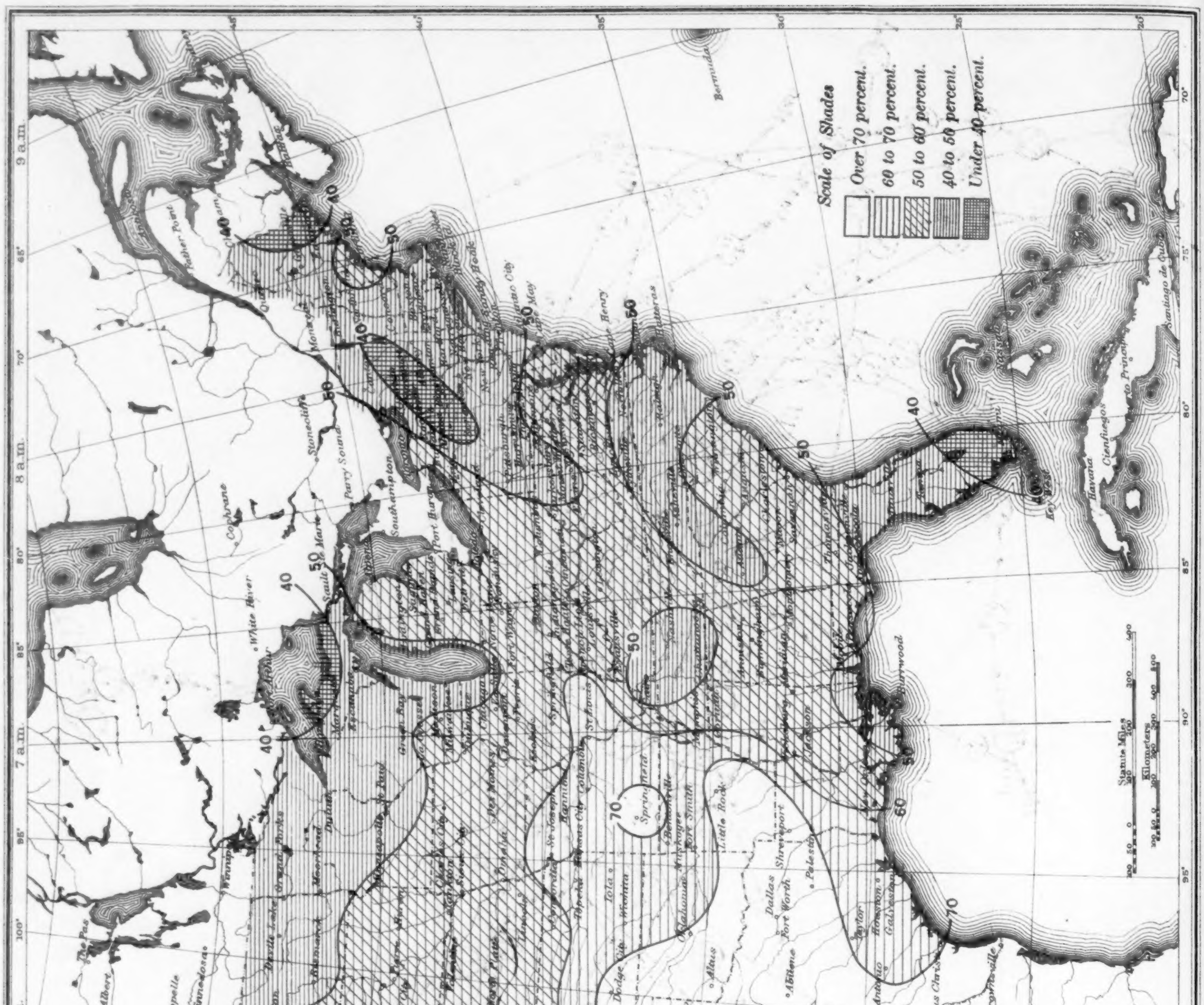


Chart V. Total Precipitation, Inches, June 1934. (Inset) Departure of Precipitation from Normal

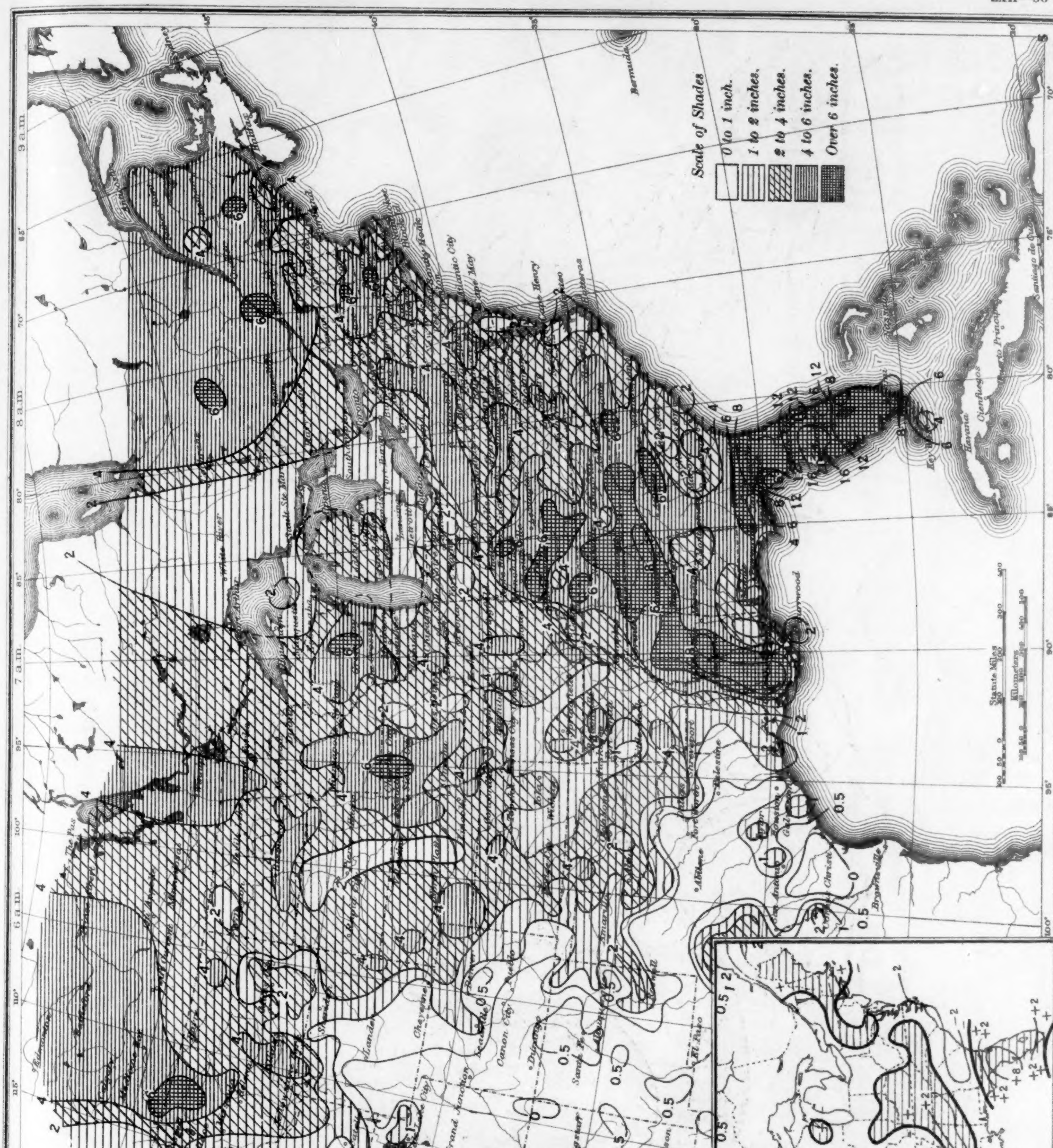


Chart V. Total Precipitation, Inches, June 1934. (Inset) Departure of Precipitation from Normal

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Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, June 1934

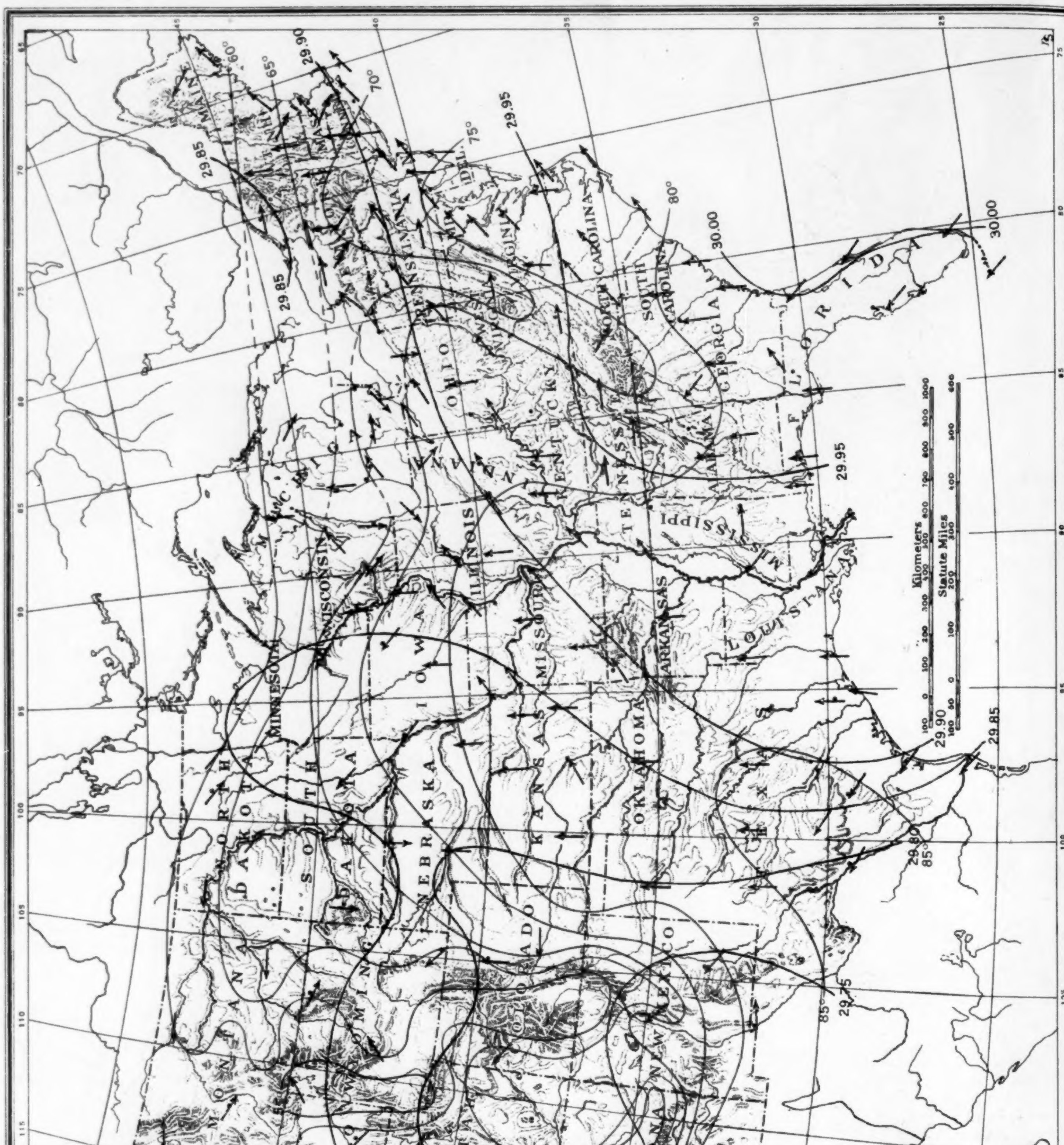

Chart VIII. Weather Map of North Atlantic Ocean, June 16, 1934
(Plotted from the Weather Bureau Northern Hemisphere Chart.)

Chart VIII. Weather Map of North Atlantic Ocean, June 16, 1934
(Plotted from the Weather Bureau Northern Hemisphere Chart)

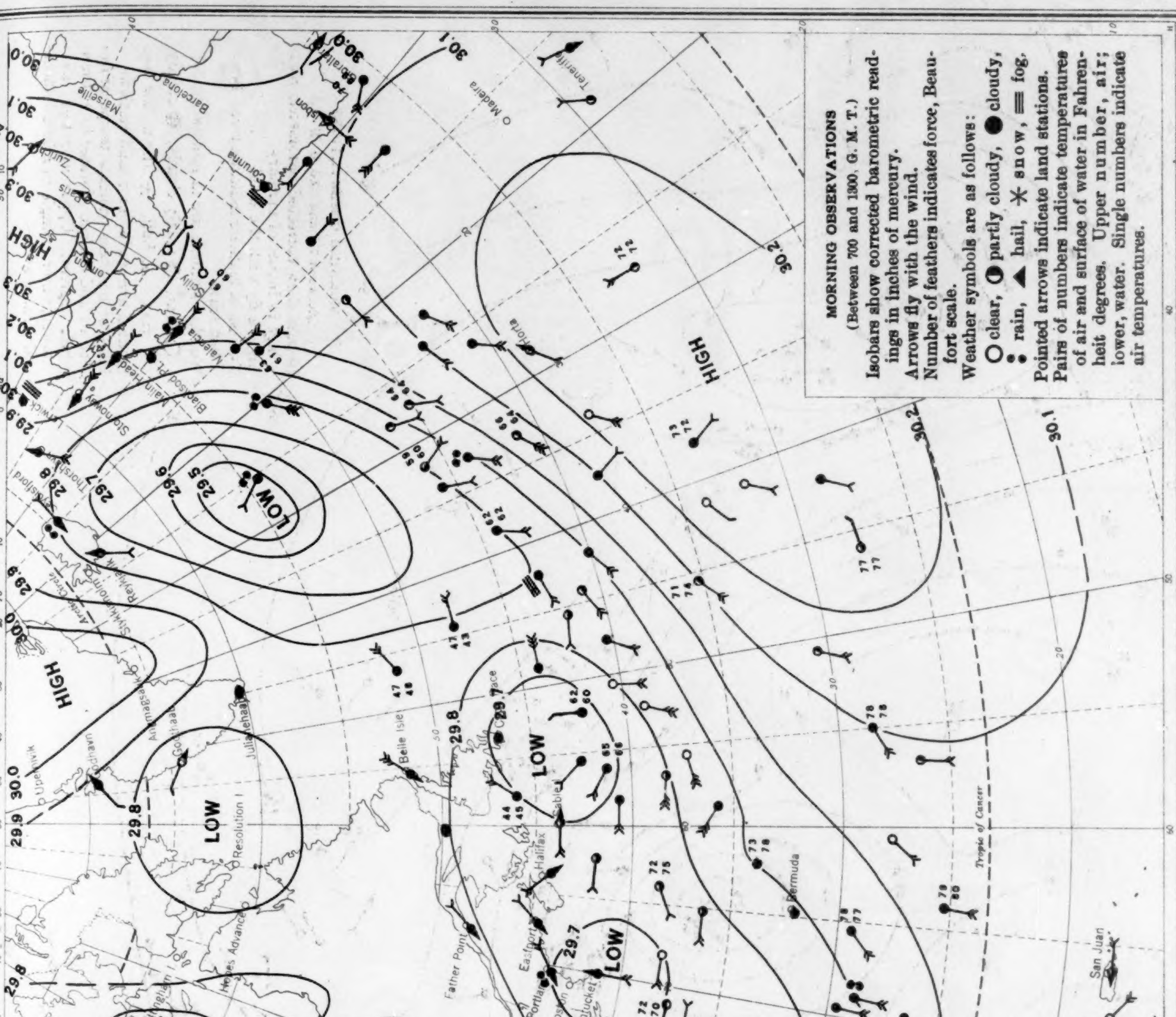

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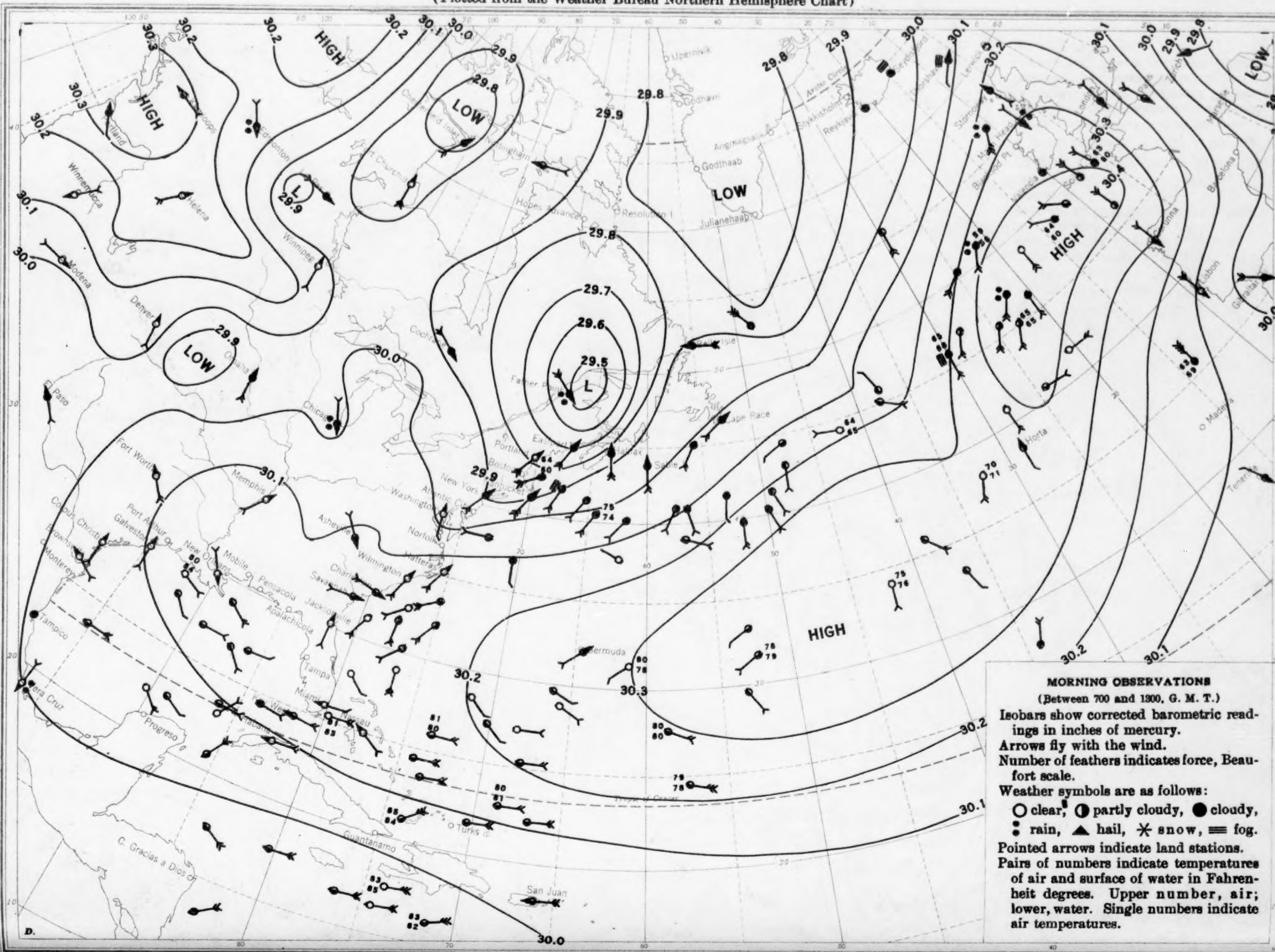
Chart IX. Weather Map of North Atlantic Ocean, June 29, 1934

(Plotted from the Weather Bureau Northern Hemisphere Chart)



MORNING OBSERVATIONS

(Between 700 and 1300, G. M. T.)

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicates force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁚ rain, ▲ hail, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water. Single numbers indicate air temperatures.